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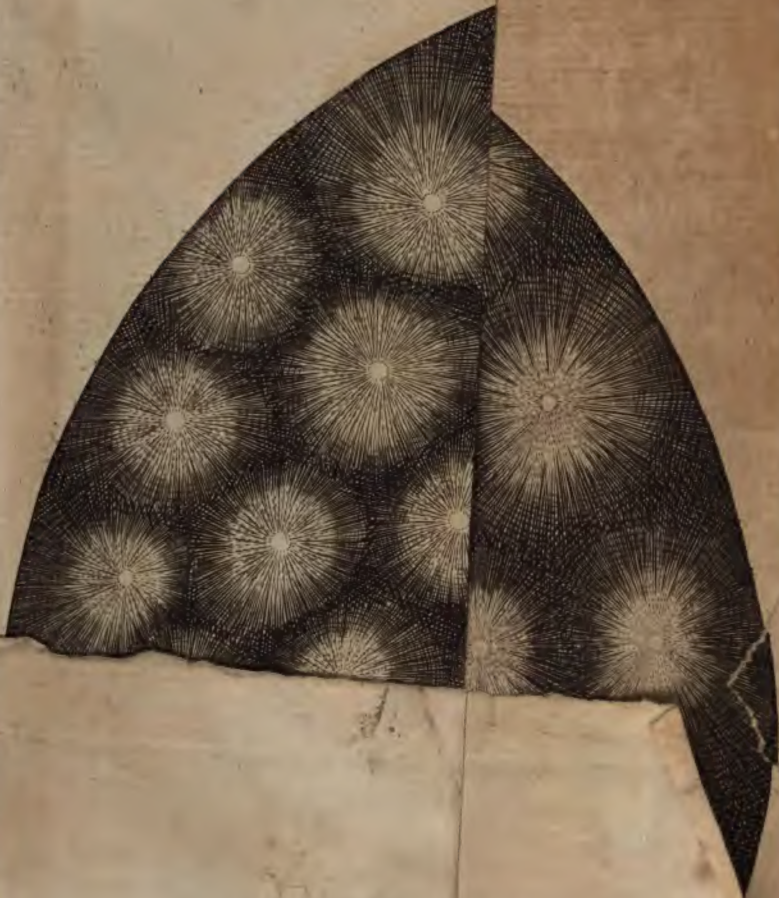

Presented by Mr Rowell

PHILOSOPHICAL ESSAYS,

In THREE PARTS.

CONTAINING

I. An Enquiry into the Nature and Properties of the Electrical Fluid, in order to explain, illustrate and confirm the truth of Sir Isaac Newton's Doctrine of a *Subtile Medium* or *Æther*.

II. A Dissertation on the Nature of Fire in general, and Production of Heat in particular.

III. A Miscellaneous discourse, wherein the forementioned active Principle is shewn to be the only probable mechanical Cause of Motion, Cohesion, Gravity, Magnetism, and other Phænomena of Nature.

To which is subjoin'd, by way of Appendix, a clear and concise Account of the Variation of the Magnetic Needle or Mariner's Compass; by which the Longitude is investigated on the most simple Principles.

And, to render the whole more intelligible, a Glossary of Terms is added.

By R. LOVETT, LAY-CLERK,
Of the *Cathedral Church* of WORCESTER.

A Fool *may find what a* wise Man *hath overlooked.*

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ERRATA.

At the end of the Preface inſtead of the Catch-
word *Chap.* it ſhould be *Subſcribers*

Page 65, line 3. for 138 read 136 [*Chap.*

p. 45, l. 26. for, *at the beginning*, read, *in the* 11th

p. 112, l. 9. for *paricularly* r. *particularly*

p. 220, l. 29. for *Cruſibles* r. *Crucibles*

for 366 r. 388 p.

p. 438, l. 16. for *concluſſon* r. *concluſion*

p. 503, l. 5. after 104° 31′ 26 r. *as appears by the preceding Table*

p. 507, l. 17. r. *Longitude from London* 74°

p. 512, l. 8. after magnetic Meridian in degrees r. *find the ſide* Cm and

THE PREFACE.

IF Men of Genius and polite Literature have confessed their particular embarrassments for want of proper Apologies, whenever they have addressed the public, the World may judge with what anxiety the Author of the following Sheets must be affected; who, though fully sensible of the want of a learned Education, yet ventures to publish (with the greatest diffidence indeed and humility) his Sentiments on so delicate and mysterious Subjects as Electricity and Fire.——It was, if I mistake not, in the Year 1739, *that I was equally suprised and delighted at the performance of many curious Experiments exhibited by the ingenious Dr.* Desaguliers, *when, none in the whole Course of his Lectures made so deep an Impression as those relating to Electricity, altho' they were effected only with a glass Tube.*

Those pleasing Ideas were much improved, when the electrical Machine was introduced, by which means the force of the Fluid was render'd still more conspicuous, and every observer saw and concluded that it was real Fire.

Since that Time Electricity hath been the principal Object both of my Study and Practice; and tho' in many respects unqualified for an Author, yet have I from a pure

regard for Truth, and a love of my fellow Creatures, already offer'd four Pamphlets on the same Subject to the Public.

My Intention at first was only to ascertain some remarkable Cures performed on the human Body by the electrical Virtue; remarkable I call them, since several of the Maladies were deemed beyond the power of common Medicine, having baffled all the efforts of the sanative Art; and therefore I can assert with Truth, that they very much exceeded my most sanguine expectations.

What prompted me to apply those Experiments to human Disorders, was some printed Accounts of the healing Virtues of Electricity; wherein a variety of extraordinary Cures were said to be performed, and which for the most part appeared well attested.

That such a number of Cures, as I was about to publish, might be fixed on a solid Foundation; and that such salutary Effects might be reasonably expected from this surprising Agent, just then discovered, I was induced to publish my Sentiments concerning it; when, I openly declared my real opinion of it, without the least reserve, viz. That it must be the same ætherial Medium, which Sir Isaac Newton *had conjectured to exist in gross Bodies, and which he had in his Optics and elsewhere described.*

This, I thought, I might very safely assert; since I was able to demonstrate from the most convincing facts, that it existed in the pores

of

of gross Bodies, and was endued with all the most remarkable and essential qualities and properties, which he had ascribed to his subtile Medium.

That part however of my Work met with a severe animadversion from the Authors of the monthly Review, as deviating too much from the language of the Newtonian Philosophers. This was the Cause of my publishing a second part in Vindication of the first, wherein I maintained the exemption of this electrical Fluid from all Newtonian Laws, and appealed to the authority of Sir Isaac Newton *himself.—— Their Answer to this was the Cause of my third, and in like manner of a fourth, which put an end to the Controversy.*

But however irksome this dispute was, it had one good Effect, and was of such real use to me, that many Things which I only conjectur'd at first setting out, were, by repeated Experiments, clearly demonstrated, and above all, that my Sentiments in the first part, concerning the identity of the two supposed Fluids, appeared to be for the most part just and well founded.

I was perhaps the first, that ever maintained that the electrical Fluid and the Newtonian Æther were one and the same, at least, of any who carried their Sentiments to any considerable length; for soon after the discovery of the Leyden Experiment, and of others subsequent to it, Bishop Berkeley's *modern plan on Æther and Fire came to my Hand. Indeed I had taken*

a superficial View of it before, when it made no great Impression on me, it appearing at that Time no more than an ingenious Hypothesis; but now it appear'd in a Light, as much superior to what it did before, as the Completion of a Prophecy does excel the Prediction; for what was foretold in that learned Treatise, was minutely realized and confirmed by the electrical Experiments. Soon after this, appeared the ingenious Dr. Franklin's *Letters upon the same Subject, which more and more confirmed me in my Opinion, since there I found many accurate Experiments which so manifestly proved the wonderful Elasticity, the exquisite subtilty, and inconceivable force of this Fluid, that not one doubt remained any longer about the Identity of those (as suppos'd)* two *subtile Fluids. There the curious Reader may see it demonstrated, to be a most powerful Fire, equal to that of Lightning, and as capable of producing the same Effects, such as melting of Metals in an Instant, &c. There likewise is discovered the Method to collect the same Fire from the Clouds, and to make all the Experiments from the Fire thus obtain'd, as with that collected at the electrical Apparatus; from which it may be irrefragably concluded, that Lightning and the electrical Fluid, are strictly and precisely the same.*

It hath ever been my wish, that some Genius of Learning and establish'd Character in the philosophic World would, instead of myself, have under-

undertaken this Subject of Electricity, and from clear and repeated Experiments, deduc'd such observations, as might merit the attention, and gain the approbation of the Public.

A Report indeed has prevail'd, that a celebrated Professor in foreign parts, had attempted to have written an intelligible System of it; but in the prosecution, he met with insuperable difficulties, found many of the Experiments so irreconcileable with each other, and so little reducible to the known Rules or common Laws of Motion, that he was oblig'd to give over the Subject as altogether inexplicable.

Had this learned Professor been in earnest, He would not, surely, so soon have desisted and been discouraged; since no natural Agent was ever more easy of Access; none ever solicited, and, as it were, courted our examination in so familiar and inviting a manner; it appearing actually to exist in almost every object we can see or handle: And let me add to all this, that so simple an Instrument as a common glass Tube, when rubb'd with the Hand, is sufficient to effect some of the capital Experiments. But

That this Electric matter is not subject to the same rules or laws of other Matter is most certainly a Concession that will be very readily granted, and therefore, the common Postulatum, that Matter differs from Matter in form only, having all other properties in common, *must consequently be absolutely false. For, let me ask, Can the primary Corpuscles of all*

Matter

Matter differ from each other in figure or form only, and yet not be subject to the same Laws? Does not this at first sight appear too unphilosophical, too absurd to be admitted?

And although all terrestrial Matter may possibly be of one Genus, *and be endued with the same properties, since it is observed to be inert and dead; yet every Electrician is well assured, that the electrical Fluid appears possess'd of real Activity, and that the particles contain'd in the Leyden Vial after being electrised, if carried Miles, will, without any additional Agitation, shew most evident Effects of Force and Activity, and frequently retain them even till the next Day.*

As to the following Essay, it is humbly propos'd only as a rough, artless Draught, in order to excite some masterly Hand *to exhibit a more perfect Model, whenever a true Genius shall arise, free from the Biass of Prejudice in favour of such Systems, that have totally excluded the subtile Medium, which is here demonstrated to exist.——The Cultivation of Electricity must ultimately depend on unprejudic'd Observers; nor can it ever be established in the World as an universal Æther, without meeting with the same opposition as all other new discoveries in the works of Nature have before it.*

In this Essay I have endeavour'd at the most methodical disposition of the several heads of Enquiry, of which I was capable; that the several Experiments *and the reasoning founded*

upon

upon them, might possibly have some faint appearance of a System: A design that was never attempted with any Success. I could therefore turn over but few Books which were of real use to me, scarce any that I knew except Dr. Franklin's *Volume of Letters, which contains many curious Experiments, and judicious Observations.*

But the Reading of many Books was not my Intention; the considering what I was sure was matter of fact, whereon to found my reasoning, was my chief and principal View.—— And here let me confess, that, sensible of my own deficiency, it is my Duty to apologise for an attempt of this Nature, rather then to plead any Thing for the merit of the Work. I might alledge also, in excuse for the many imperfections, and errors to be found in the following Treatise, that the greatest part was drawn up amidst a variety of Avocations, with frequent interruptions, in small portions of Time, and without the Assistance of any Friend that had studied the Subject sufficiently to correct or revise it.—— But, I am not insensible, that all I can say to defend it, will avail very little, unless it can defend it self.

To the public therefore let me submit it, to every impartial, unprejudiced Judge, who is capable of putting me right, humbly presuming that no sincere and ingenuous Enquirer after Truth, who reads over the whole with due Attention, will find it altogether a useless

Speculation,

[illegible] *Speculation, or cavil with me for some slight Inaccuracies in Point of* Method, Connexion, Language, *or* Grammar.

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Napier,

N.

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Oliver, Mr. *Proctor, and Chapter-Clerk*, Worcefter

P.

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Q.

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R.

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Stam-

S.

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CHAP. I.

The Origin, Antiquity, and Progreſs of Electricity. *Opinions of various Authors on* Air.

ATTEMPTS to render Electricity intelligible and plain have been ſo often made, and with ſo little ſucceſs, that the Expectation of the Public is almoſt at an end; and 'till ſome more effectual method be purſued than what has been hitherto practis'd, ſo long that wonderful Appearance of Nature will remain inexplicable. Therefore, that one ſo unaccompliſh'd and unlearned as I muſt own myſelf to be, ſhou'd preſume to explain it, will doubtleſs be thought a vain and daring Effort, by MANY, who may be inclined to think that little more can be produced from my illiterate Labours, than from Æſop's teeming Mountain, which brought forth only a Mouſe.

2. This was ſo natural and obvious, that I could not help foreſeeing it my ſelf in the ſtrongeſt Light: The method therefore

which appear'd to me the moſt eligible and unexceptionable, in order to guard againſt ſuch an ill-favour'd Reflection, was, to collect the Opinions and Experiments of ſome of the moſt celebrated and authentic Writers on this ambiguous Subject, particularly of Sir I. *Newton*, Mr. *Haukſbee*, and Dr. *Franklin*; to lay their obſervations together; to compare them diligently and candidly; and to make uſe of whatever I found proper for my fixed purpoſe of inveſtigating the Truth.

3. By ſuch a careful, and, I think, rational method of proceeding, together with my own Experiments and Obſervations, I was encourag'd to hope that ſome farther Light might be reflected on this important Subject than ever was before.

4. But in order to elucidate, and render it more inſtructive and entertaining to the Reader, I muſt beg leave to prefix a brief account of the Origin, Antiquity, and Progreſs of it.

5. This I in ſome meaſure anticipated by a former Publication; but as I have many Things to add to the Obſervations I then made, I now take the Liberty to place the whole here in one regular View.

6. The Term Electricity in great meaſure explains it ſelf, being deriv'd from *Electron*, which is the Greek Name for Amber.

7. The Ancients, ſome thouſand Years ago, were not unacquainted with that Property in

Amber of attracting light Bodies after rubbing it; for which Reafon all other Things that were afterwards found to be endu'd with the like Qualities of Attraction, *&c.* were call'd Electrics, and all others, Non-electrics.

8. The Reafon why Electricity made fuch flow Advances in the experimental Way, for fo many hundred Years, was, from its not being known that it efcap'd thro' other Bodies into the Earth; and more particularly from not knowing that all fuch Bodies, which are now call'd Electrics *per fe*, were the only Bodies which could prevent fuch Efcape.

9. Of Bodies which are endu'd with this Quality, Glafs is found to be one of the greateft of all, even much to exceed that of Amber itfelf.

10. The very firft Man that we hear of, who was fo happy as to make any confiderable Improvement in Electricity, is Mr. *Haukfbee*, Fellow of the Royal Society, near the latter end of the laft Century; he difcover'd many of the Experiments, that are now exhibited, with a glafs Tube; he alfo invented a method to turn glafs Globes and Cylinders on their Axes, and nearly of the fame Conftruction with thofe that are now made ufe of, fome in the common Way, others he exhaufted of their Air, and then whirl'd them on their Axes, and exhibited the appearance of Fire in various forms, and in fome, in very great plenty.

11. The next confiderable Improver of Electricity was Mr. Stephen *Gray*, of the Charter-houfe, who fpent no fmall part of his Time in making fuch kind of Experiments, ftill improving on Mr. *Haukfbee's* glafs Tube; but tho' we never heard that he made ufe of the revolving Globe or Cylinder, as Mr. *Haukfbee* did, yet he carry'd his Refearches much farther than he, and from the great number of Experiments made by him, he may truly be faid to have fet on foot all the Difcoveries that have been fince made on that curious Subject.

12. Dr. *Defaguliers* in the 1ft Vol. of his Courfe of experimental Philofophy, p. 450, tells us, that Mr. *Gray* had made a greater variety of electrical Experiments than all the Philofophers of this and the laft Age*.— It was he who difcover'd that Glafs, Amber, Refin, Wax, Silk, Hair, and all other electric Bodies, did not convey the electric Matter to other Bodies, nor fuffer it to efcape thro' them like Metals, Water, Animals, and fome others, and confequently if he fupported the latter with the former, he might convey it to diftant parts; this difcovery was productive of

* Notwithftanding this is true, and tho' the World is greatly indebted to him for fuch indefatigable Pains and Induftry; yet it muft be own'd, that it is much more indebted to Mr. *Haukfbee* for pointing out the means.

another, viz. that ſuch propagation of it to diſtant Bodies ſeem'd inſtantaneous, he himſelf having experienc'd it to be ſenſibly ſo, to the diſtance of 800 feet.

13. It was he who diſcover'd it to eſcape into the Earth, and having likewiſe diſcover'd, that what are ſince call'd electrics *per ſe* would prevent ſuch eſcape, his method was to ſuſpend a Perſon horizontally on two *hair or ſilk Lines*, then rubbing his glaſs Tube, and holding it near his Feet, his Face or Hands were inſtantly capable of attracting and repelling light Bodies.

14. He afterwards diſcover'd that more commodious method of electriſing a Perſon, viz. By ſetting him on a Cake of Reſin, Glaſs, or any other electrical Subſtance, and that it was equally the ſame as ſupporting him with hair or ſilk Lines.

15. A greater Improvement yet, was the introducing of the glaſs Globe, Cylinder, and Spheroid whirling on their Axes, inſtead of rubbing the glaſs Tube, the Power being by that means increas'd to a very high Degree.

16. Thus having brought it to ſuch Perfection, a great Number of various Experiments were every where made, particularly after it was diſcover'd ſo plainly to be Fire, as to kindle up many particular Bodies into an actual Flame.

17. But the greateſt Improvement of all, and what conducted to the finiſhing Stroke,

was the accidental and ſurpriſing Shock, diſcover'd *to* Profeſſor M. de *Muſchenbroek* of Leyden: An Account of which was communicated in a Letter from Paris, and was as follows:

18. March 25th 1746. M. de *Muſchenbroek*, a famous Profeſſor of experimental Phyſics at Leyden, has wrote a Letter to M. de *Reaumur*, of the Royal Academy of Sciences, containing an Account of a very ſingular Experiment, which has led him to ſeveral Diſcoveries concerning Electricity.

The EXPERIMENT.

19. Having ſuſpended an iron Cannon horizontally, upon ſilken Cords, with one end near the electrical Globe, he faſtened to the other end a latten Wire, which deſcended into a Bottle half full of Water; that holding up the Bottle with one Hand, while the Cannon was electriſing, he put forth a Finger of his other Hand towards the Piece, in order, as uſual, to draw off a Spark, but was ſtruck ſuch a violent blow, that he thought his Life was at an end; and adds, that, eſteeming himſelf very happy in eſcaping, he had no mind to repeat the Experiment, and that the Commotion he felt was like a Clap of Thunder.

20. As this Letter came at a Time when many learned Men were employ'd about Electricity, the Abbe *Nollet* and M. de

Monniers

Monniers, of the ſame Academy, zealous to ſearch into ſo extraordinary a Phænomenon, diveſted themſelves of Fear, made the ſame Experiment as M. de *Muſchenbroek* had done, and, in like manner, found the Commotion very terrible.

London Evening Poſt, April the 1ſt, 1746.

21. This ſudden and wonderful Diſcovery amazed the whole European World a conſiderable time; for before this, very little, if any Power or Force was perceiv'd in Electricity or even ſuſpected; ſo that now it appear'd ſo much to exceed the Power of what was found in it before, as to bear ſcarcely any Manner of Proportion; for inſtead of being ſtrong enough to be felt to puſh againſt the Finger (which, before this, was counted a great Matter) it was now found much more capable of moving a Mountain, and, from the great Number of Experiments which were ſoon made in all Places, the Progreſs of its clearer and clearer Diſcovery was, from that Time, exceedingly rapid.————Having myſelf clearly diſcovered, by a repeated Courſe of Experiments, that *Air* is a principal Agent in producing thoſe wonderful electrical effects, which have of late years ſo juſtly engag'd the attention of the curious, it naturally conducted me, who have devoted a conſiderable portion of my time to thoſe Studies, (particularly ſince Profeſſor *Muſchenbroek* diſcover'd the above-mentioned wonderful force of the electrical fluid) to enquire

quire more particularly into the nature, properties, and conſtituent parts of the Atmoſphere, or common Air; and as *Chambers* in his Dictionary gives us the Sentiments of the moſt approv'd Writers on that Subject, I apply'd to him, who informs us,

22. ' That *Air* in Phyſics, is a thin fluid, ' tranſparent, compreſſible and dilatable Body, ' ſurrounding the terraqueous Globe to a ' conſiderable height.'

23. ' Air was conſider'd by ſome of the ' Ancients, as an Element, but then by ' Element they underſtood a different thing ' from what we do.'

24. ' 'Tis certain that Air taken in the po- ' pular ſenſe is far from the ſimplicity of an ' elementary ſubſtance; tho', there may be ' ſomething in it which bids fair for the appel- ' lation. —— Hence Air may be diſtinguiſh'd ' into vulgar or heterogeneous, and proper or ' elementary.'

25. ' Vulgar or heterogeneous Air is a coa- ' lition of corpuſcles of various kinds, which ' together conſtitute one fluid maſs, wherein ' we live and move, and which we are conti- ' nually receiving and expelling by reſpiration; ' the whole aſſemblage of this makes what we ' call the Atmoſphere.'

26. ' The ſubſtances whereof Air conſiſts, may be reduc'd to two kinds, viz. Firſt, the ' Matter of light or fire: —— Secondly, thoſe ' numberleſs particles, which in form either

' of

'of vapours or dry exhalations, are rais'd from 'the earth, water, minerals, vegetables, ani- 'mals, *&c.* either by the ſolar, ſubterraneous, 'or culinary Fire.'

27. 'Elementary Air properly ſo called, is 'a certain ſubtle homogeneous elaſtic matter, 'the baſis or fundamental ingredient of the 'atmoſpherical Air, and that which gives it 'its denomination.'

28. 'The peculiar nature of this pure æ- 'therial Matter we know but little of; what 'Authors have advanced concerning it being 'chiefly conjectural. We have no way of ex- 'amining it apart, or ſeparating it from the 'other heterogeneous Matters it is mixed with, 'and conſequently no way of aſcertaining with 'evidence what belongs to it abſtractedly from 'the reſt.'

29 'Dr. *Hook* and ſome others will have 'it to be no other than the Æther itſelf, or 'that fine, fluid, active Matter, diffus'd thro' 'the whole expanſe of the celeſtial regions; 'which coincides with Sir Iſaac *Newton*'s 'Subtile Medium or Spirit.'

30. 'In this view it is ſuppoſed a Body, *ſui* '*generis*, ingenerable, incorruptible, immuta- 'ble, preſent in all places and in all bodies.'

31. I alſo conſulted the learned Biſhop *Berkeley*'s Siris, where he appears to have taken great pains in examining the nature and properties of the Atmoſphere, and adopted many of the opinions of the ancients on the ſame.

32. At Section 137, he tells us, that, ' the
' Air or Atmosphere, that surrounds our earth,
' contains a mixture of all the active volatile
' parts of the whole habitable world; that is,
' of all vegetables, minerals, and animals.
' Whatever perspires, corrupts, or exhales, im-
' pregnates the Air, *&c.* '

33. ' The perpetual oscillations of this
' elastic and restless element operate without
' ceasing on all things that have life, whether
' animal or vegetable, keeping their fibres,
' vessels, and fluids in a motion always chang-
' ing, as heat, cold, moisture, dryness, and
' other causes, alter the elasticity of the Air;
' which accounts, it must be own'd, for many
' effects. But there are many more which
' must be deriv'd from other principles or qua-
' lities in the air. Thus iron and copper are
' corroded and gather rust in the air, and bo-
' dies of all sorts are dissolv'd or corrupted,
' which sheweth an acid to abound and diffuse
' itself throughout the air.' Sect. 138.

34. ' By this same air, Fire is kindled, the
' lamp of life preserv'd, respiration, digestion,
' nutrition, the Pulse of the Heart, and motion
' of all the Muscles seem to be performed.
' Air therefore is a general agent, not only
' exerting its own, but calling forth the qua-
' lities or powers of all other bodies, by a
' division, comminution, and agitation of their
' particles, causing them to fly off, and become
' volatile and active. ' 139.

35. 'Nothing ferments, vegetates, or pu-'trefies without air, which operates with all 'the virtues of the bodies included in it, that 'is, of all nature; there being no drug, falu-'tary or poifonous, whofe virtues are not 'breathed into the air. The Air therefore is 'an active mafs of numberlefs different prin-'ciples, the general fource of corruption and 'generation; on one hand dividing, abrading, 'and carrying off the particles of bodies, that 'is, corrupting, or diffolving them; on the 'other, producing new ones into being, de-'ftroying and beftowing forms without inter-'miffion.' 140.

36. 'The feeds of things feem to lye latent 'in the air, ready to appear and produce their 'kind, whenever they light on a proper ma-'trix. The extremely fmall feeds of fern, 'moffes, mufhrooms, and fome other Plants, 'are concealed, and wafted about in the Air, 'every part whereof feems replete with feeds 'of one kind or other. The whole atmofphere 'feems alive. There is every where acid to 'corrode, and feed to engender. Iron will 'ruft, and mould will grow in all places. Vir-'gin-earth becomes fertile; crops of new 'plants ever and anon fhew themfelves; all 'which demonftrates the Air to be a common 'feminary and receptacle of all vivifying prin-'ciples.' 141.

37. 'That there is fome latent vivifying 'fpirit difpers'd throughout the air, common

'experience sheweth; inasmuch as it is ne-
'cessary both to vegetables and animals, whe-
'ther terrestrial or aquatic, neither Beasts, Insects,
'Birds, nor Fishes, being able to subsist with-
'out air. Nor doth all Air suffice, there being
'some quality or ingredient, of which, when
'air is deprived, it becometh unfit to maintain
'either Life or Flame. And this, even tho' the
'air should retain its elasticity; which by the
'bye, is an argument that Air doth not act
'only as an antagonist to the intercostal mus-
'cles. It hath both that and many other uses.
'It gives and preserves a proper tone to the
'vessels: This elastic fluid promotes all secre-
'tions: Its oscillations keep every part in
'motion: It pervades and actuates the whole
'animal system, producing great variety of ef-
'fects, and even opposite at different parts,
'cooling and heating at the same time, dis-
'tending and contracting, coagulating and
'resolving, giving and taking, sustaining Life
'and impairing it, pressing without and ex-
'panding within, abrading some parts, at the
'same time insinuating and supplying others,
'producing various vibrations in the Fibres,
'and ferments in the Fluids; all which must
'needs ensue from such a subtile, active, he-
'terogeneous and elastic fluid.' 143.

38. 'But there is, as we have observed,
'some one quality or ingredient in the air, on
'which Life more immediately and princi-
'pally depends. What that is, tho' Men are
'not

'not agreed, yet it is agreed, it muſt be the 'ſame thing that ſupports the vital and the 'common flame, it being found, that when 'air, by often breathing in it, is become un-'fit for the one, it will no longer ſerve for the 'other, *&c. &c.*' 144.

39. *N. B.* This and much more to the ſame effect is contain'd in the Biſhop's Siris, or eſſay on the virtues of Tar-water.

40. When I had perus'd the above account, concerning ſuch remarkable properties of the atmoſphere, it appear'd, eſpecially at firſt, quite incredible; particularly where he endeavours to ſhew, that the Air by virtue of ætherial Fire contain'd therein, includes the ſpermatic forms of all natural things: —— 'The 'ſeeds of things ſeem to lye latent in the air, 'ready to appear and produce their kind: —— 'that every part of the air ſeems replete with 'ſeeds of one kind or other: —— that the 'Element of ætherial Fire or Light ſeems to 'comprehend in a mix'd ſtate, the Seeds, the 'natural Cauſes and Forms of all ſublunary 'Things,' and the like.

41. Not being accuſtom'd to ſuch kind of Reaſoning, it appear'd ſo extravagant, that I thought to have paſſed over that part without farther notice.

42 But when I conſulted the renown'd *Boerhaave* on the ſame Subject, I was ſoon made ſenſible of my miſtake; for he not only confirms what I thought ſo improbable in general,

but plainly demonſtrates that the air is capable of containing things of the moſt ponderous nature. I ſhall therefore tranſcribe his own words, who, when reaſoning with his Pupils concerning air, thus expreſſes himſelf.

43. ‘ Foſſils, I am certain, are likewiſe ‘ diſcover'd in the air. Foſſils, ſay you in the ‘ air! 'twere as reaſonable to ſuppoſe Caſtles ‘ there. But pleaſe to hear only what I have ‘ to offer upon this head, and then you your- ‘ ſelves be judges.

44. ‘ Do not then all foſſil ſalts whatever, ‘ tho' ever ſo fix'd, if they are diſſolv'd in wa- ‘ ter (eſpecially in that which you attract from ‘ air) and are afterwards digeſted for a long ‘ time in a putrifying heat, and are then diſ- ‘ tilled with a great degree of Fire, and have ‘ their fix'd Reſiduum calcin'd with a ſtrong ‘ open one, and then diſſolv'd in the air: Do ‘ not, I ſay, all foſſil ſalts whatever, managed ‘ after this manner, at length fly off into the ‘ air? This is a Truth which a great Chy- ‘ miſt communicated to the World more ‘ than an Hundred Years ago. Not to men- ‘ tion the diſtillation of theſe Salts, with ‘ Sand, Bole, Brick-duſt, Potters, and Tobac- ‘ co-pipe Clay, performed with the intenſeſt ‘ Heat! Do not the Chymiſts every Year con- ‘ vert, by this method, many thouſand pounds ‘ weight of ſuch Salts, into acid volatile ‘ Fumes, which they call Spirits? And does ‘ not every ſuch chymical Operation infect

‘ the

'the air? And does not this Air deſtroy the
'Bodies that are expoſ'd to it? The ſingle
'and ſimple mixture of Oil of Vitriol, oil of
'Allum, oil of Sulphur by the Bell, with
'Nitre, Sea-ſalt, or Salt-gem, converts in an
'inſtant thoſe very fix'd Salts into Fumes, ſo
'volatile, that they can hardly be confin'd;
'with which the Air is in a ſhort Time ſo
'ſtrongly impregnated, as to carry thoſe Salts
'to great diſtances all around. But infinite
'are the methods by which the ſame Thing
'is affected.' And farther on. ——— 'In the
'laſt place, Metals themſelves have been ſo far
'changed, that they likewiſe, under the form
'of a volatile Fume, have been ſcattered up
'and down in the air. This is univerſally
'known to be true of Mercury, which when
'agitated only by a Fire of 600 Degrees, flies
'off, and becomes inviſible. And if the Air
'impregnated with it, ſurrounds, and is ap-
'plied to a human Body, how wonderfully
'does it penetrate it, and how quickly does
'it throw it into a Salivation! But beſides,
'while it thus flies off, it carries up and bears
'away with it ſome part of certain Metals; as
'appears from the diſtillation of Lead and
'Tin with Mercury. Nay, Lead, Tin, Iron
'and Copper, if they are diſpoſ'd in a very
'ſtrong Heat, at length diſappear, by means
'of the Volatility they acquire there, and thus
'far are diſſipated likewiſe into the air. A
'great part of imperfect Metals is carried off

'too by Lead in the Teſt. But when Cobalts, 'Arſenics, and the like rapacious Sulphurs, 'are intimately united with Gold and ſilver 'Ore, the particles of the Ore being by this 'means render'd volatile, when they come to 'the Fire, they carry away theſe noble Metals 'to that degree, that to the great damage of 'the Owner, a good part of them both is loſt, 'which by a gentle calcination, and the ad-'dition of ſome fixing Powders, might be 'entirely preſerv'd. Hence, therefore, it ap-'pears, what an abundance of Gold and 'Silver may be raiſed up into the air. No-'thing, indeed, ſeems a greater Paradox, than 'volatile Gold, and yet we are certain from 'undeniable chymical Experiments, that if 'you take common ſublimate of Mercury, 'and rub it well with Gold reduc'd to Pow-'der, and then diſtill it in a Retort with re-'gulus of Antimony, the very Body of the 'Gold will aſcend in form of a red Oil, and 'become perfectly volatile. By Sulphur like-'wiſe, calcin'd Vitriol, and Sal-ammoniac, 'mix'd and apply'd according to Art, almoſt 'all Metals may be render'd volatile in the 'Fire. No wonder then, that in clear Wea-'ther, there very often appears about Mines 'ſudden Fumes, which extinguiſh the Light 'of a Torch. See *Boyle*'s Works. vol. 1ſt, 'p. 52. Since even the moſt denſe Bodies may, 'in the form of a Fume, be ſo carried up 'into the air, as that it can hardly be deter-

'min'd

'min'd what Bodies they were. But there is 'another Cause which is frequently concerned 'in this Affair, and which likewise impreg-'nates the Air with these metallic parts, and 'that is the Air it self abounding with Salts 'and Sulphurs. For as I have already shewn 'above that the whole Air is full of Salts 'and Sulphurs, and as it appears from what 'I have now deliver'd, that those Salts and 'Sulphurs can carry aloft even Metals them-'selves when they are dissolv'd, it is easy to 'apprehend, that the Air it self can by this 'means effect that the parts of Metals may 'be suspended and float about in it.'

45. 'Before we leave the examination of 'the various Bodies, that are contained in the 'Air, and of the different Powers which pre-'vail in it, we must yet take under conside-'ration one quality of it, which is very salu-'tary and necessary to the Life of Animals 'and Vegetables; a quality which has not yet 'been accounted for from any other property 'of the Air; but by a diligent inquiry, how-'ever, may possibly, hereafter, be come at the 'Knowledge of. Whether, now, this latent 'virtue of the Air is actually drawn out of it 'by Animals and Vegetables, and hence is in 'a short Time exhausted and consumed; and 'whether, when it does thus fail, the Ani-'mal dies, no body is, I think at present, able 'to determine. This however is certain, that 'if a small Bird is put into a large Receiver

'full of common cold Air, and the Receiver
' is then very closely stopp'd, the Bird will
' grow sick and vomit within a quarter of an
' hour, and die in the space of half an hour
' after. *Boyle* on the *Air*. p. 184.——A Fish
' kept in Water, in a vessel well closed, with-
' out renewing the Air, dies in a short
' time. Fish likewise die in ponds, that are
' every where frozen over, and quickly perish
' in Water, out of which the Air is exhausted.
' *Hist. de l' Acad. Roy. des Scien.* 1699. 240.
' 1701. 46., and *Mem.* 224.——Flame, and
' a red hot coal, quickly go out in air, that is
' close pent in. The little Eggs of any Insects
' whatever, being accurately stopt up in glass
' vessels, do not produce their young, though
' assisted by a kindly warmth. The Seeds of
' Plants likewise duly moistened, and sow'd
' in the best Earth in close Glasses, do not grow,
' or give any signs of active Life, tho' excited
' by a due degree of heat. On the other hand,
' the upper surface of Blood, that is expos'd to
' the Air, is of a bright scarlet colour, whilst
' in every other part, where the air don't come
' at it, it grows as black as the juices of a Cut-
' tle-fish: And yet, as soon as ever this black
' part is laid open to the air, the black colour
' is immediately chang'd again into a scarlet:
' All these experiments then make it appear;
' that there is in the air a certain hidden vir-
' tue, which cannot be accounted for from the
' properties of the air, which have been hi-

' therto

'therto discover'd. *Sendivogius* maintain'd it 'openly, that there lies hid in the air, the 'occult Food of Life; and other Chymists 'have asserted the same: But what that is, 'or how it acts, or what is the proper effect 'of it, is a matter still in the dark, Happy the 'Person that shall happen to discover it. Let 'this hint suffice for Persons that are ignorant 'of it, Is it not the elastic Part of the Air 'alone?'

46. 'For my own part, I confess, I cannot 'apprehend, that either the natural Philoso'phers, or Physicians, have yet discover'd the 'physical cause of this wonderful quality of 'air. I have seen indeed a great many conjec'tures upon it; but they have almost all fallen 'of themselves.' *Dallow's Translation* of *Boerhaave's Theor.* of the Art of Chym. p. 292.

CHAP. II. PART I.

SECTION 47.

Sir Isaac Newton's *Rules of Reasoning in Philosophy. And, the* Author's *First Principles.*

AFTER having consulted those respectable Authors, mentioned in the preceding Chapter, upon Air, and throughly and strictly examined the electrical Fluid, by means of the most effectual Experiments, that I could either meet with or invent, and varied and changed them into many different forms, I diligently compared the electrical fluid with the description that had been given of air; and considering the whole with the utmost attention and accuracy, I was convinced of the truth of many things, which they had advanced, since it was no more than I myself saw verified at the electrical apparatus.

48. When a Writer undertakes to explain and settle any important point, which before was doubtful, his First Principles should be rational, and his Method perspicuous: In order to which, I shall lay down my first and funda-

mental Principles in such a manner, as to serve for so many Heads of a Theory of the Air; which Theory I shall investigate by a kind of Practice, *i. e.* Experiments: And this I shall endeavour to effect with such clearness and plainness, that those Heads, or first Principles may supply the place of a Criterion, or Touchstone, whereby to prove the validity of my Conclusions; and if they be thought unsatisfactory, or insufficient, by any of my Readers, let them be tried by Sir *Isaac*'s excellent Rules of Reasoning, which are as follow:

49. Rule I. *We are to admit no more Causes of natural things than such as are both true and sufficient to explain their appearances.*

To this purpose the Philosophers say, that Nature does nothing in vain; and more is in vain, when less will serve.

Rule II. *Therefore, to the same natural effects, we must, as far as possible, assign the same causes.*

Rule III. *The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our Experiments, are to be esteem'd the universal qualities of all bodies whatsoever.*

Rule

Rule IV. *In experimental Philosophy we are to look upon Propositions, collected by general Induction from Phænomena, as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other Phænomena occur, by which they may either be made more accurate, or else liable to exceptions.* Princip. Book 3d. p. 202.

To these Rules, I have subjoin'd those Heads, or System of my First Principles, that both may be the more easily referr'd to.

SECTION 50.

FIRST, *That in the beginning, the* ALL-WISE *and* OMNIPOTENT CREATOR *of all things formed an universal ætherial Fluid or primary Air, endued with the utmost purity, subtilty, and rarity; and in fine, a perfectly subtile elastic Fluid.*

Secondly, *That the whole Universe is replete with it; for otherwise a Fluid so perfectly subtile and elastic would be perpetually*

petually expanding, till all parts were equally full; and then neither the whole nor its parts could remain endued with that perfect elasticity, which was at first suppos'd, and at present appears.

Thirdly, *That this Æther or pure Air is universal, not only in all open spaces, but in the minutest vacuities of the most compact Bodies by reason of its being composed of almost infinitely finer Particles than those of gross Matter, which renders it capable of permeating the smallest Pores and Interstices of the hardest and closest Substances.*

Fourthly, *Since the Earth is endued with a property of transpiration or of breathing forth the most volatile parts of it to a considerable height from its surface; those Effluvia become blended, incorporated, and most intimately mixed with Particles of the universal pure Æther or primary Air, and by that means constitute a secondary Air*, or*

* The Atmosphere.

aerial

aërial Fluid, and the only one that could (till now) be proved to exiſt.

Fifthly, *That from the elaſticity of its Particles ariſeth an Intumeſcence, a ſwelling or expanding Property and conſtant endeavour of extending their Limits to greater dimenſions: Hence they, and conſequently all Maſſes compoſed of ſuch elaſtic Particles, mutually repel.*

Sixthly *and* Laſtly, *That this univerſal Air, altho' inviſible, is nevertheleſs true and real Fire in the ſtricteſt Senſe of the Word, and endued with the utmoſt Force.*

51. To ſhew that the learned Biſhop *Berkeley* was entirely of this Opinion with regard to common Air, the following Quotation was extracted from his *Siris.*

52. 'In common Air, he ſays, we may 'conceive two parts, the one more groſs which 'is raiſed and carried off from the Bodies of 'this terraqueous Maſs: The other a fine ſubtile Spirit, by means whereof, the former is 'render'd volatile and elaſtic. Together they 'compoſe a Medium, whoſe elaſticity is leſs 'than that of pure Æther, Fire, or Spirit, in 'proportion to the quantity of Salts, Vapours, 'and heterogeneous Particles contain'd therein.' *Siris*, Sect. 150.

53. 'It is manifest therefore, that common
'Air, is no distinct element; but a Mass, or
'mixture of things, the most heterogeneous,
'and even opposite to each other, which be-
'come Air, by acquiring an elasticity and vo-
'latility from the attraction of some active,
'subtile substance; whether it be call'd Fire,
'Æther, Light, or the vital Spirit of the World;
'in like manner as the particles of Antimony,
'of themselves not volatile, are carried off by
'sublimation, and render'd volatile, by coher-
'ing with the particles of Sal-ammoniac. But
'action and reaction being equal, the spring
'of this ætherial spirit is diminished, by being
'imparted. Its velocity and subtilty, are also
'less from its being mixed with grosser parti-
'cles. Hence Sound moves slower than Light,
'as mud than water *.' Sect. 147. ——— Hence also æther is properly no more than pure air, and common air a less pure æther; consequently they repel each other.

54. That such a number of Articles should be fix'd on as First Principles, whereon to establish the Theory of a System of Philosophy, I

* It is not my Intention to insinuate, that what is contained in these Quotations, is any real Proof of my Assertions; but to shew, that what I have here advanced, is no wild Thought of my own, but what is agreeable to Experiment, and what has been maintained by Authors of high Rank in the Republic of Letters, long before such a subtile elastic Agent was discovered.

muſt own, is ſomething unprecedented: But as Facts are ſo ſtubborn as to yield to no Reaſoning, tho' ever ſo plauſible, the following indubitable ones are exhibited, to evince that ſuch an univerſal primary Air or Æther, not only exiſts in groſs Bodies, but is alſo clearly verified to the Senſes: Univerſal I ſay, ſince it manifeſtly appears to be ſo, as far as human art and induſtry can purſue it; i. e. as far as the Clouds, and muſt therefore be allow'd. See Sir *Iſaac*'s third Rule of Reaſoning.

55. That the exiſtence of ſuch an univerſal primary Air or Æther was long ago perceiv'd, is evident from many of the Writings of the ancient Philoſophers; and the ſame doctrine has been adopted and cultivated from time to time by many eminent moderns, and particularly by ſome of our own Countrymen, as the great Lord *Bacon*, the indefatigable Mr. *Boyle*, the learned Prelate Dr. *Berkeley*, Biſhop of Cloyne, and eſpecially the great Sir Iſaac *Newton*.

56. But before I produce the Experiments that prove it to exiſt in the pores of groſs bodies, as Sir Iſaac had aſſerted, I ſhall endeavour to obviate an objection or two that may poſſibly be made to ſome particular Articles of my Theory, that they may appear to others in the ſame rational and convincing Light in which they do to my ſelf. As

57 I. What reaſonable pretence there can be for ſuppoſing two diſtinct Airs.

II.

II. What Properties the electrical Æther has in common with Air.

III. What Properties it has in common with the Æther or pure Air, *viz.* ſuch Properties of it, as are aſcribed to it by Sir Iſaac *Newton*, and the learned Prelate before mentioned.

58. *Firſt*, That the opinion of two kinds of Air, diſtinct from each other, is not a mere Novelty: This appears from *Chambers*'s Encyclopœdia, as well as from the before-mention'd Siris: And herein Biſhop *Berkeley* ſeems not only to favour ſuch an Opinion himſelf; but informs us, that 'Æther by the ancient Philoſophers was uſed to ſignify promiſcuouſly, 'ſometimes Fire and ſometimes Air. For they 'diſtinguiſh'd two ſorts of Air. *Plato* in the 'Timæus ſpeaking of Air, ſaith, there are two 'kinds, the one more fine and ſubtile, called 'æther, the other more groſs and replete with 'vapours.' Sect. 168.

Sir Iſaac *Newton* alſo ſeems to be of the ſame Opinion.

59. I. 'I ſuppoſe', ſays he, 'that there is diffus'd through all places an ætherial ſubſtance, 'capable of contraction and dilatation, ſtrongly 'elaſtic, and, in a word, *much like Air in all* '*reſpects, but far more ſubtile.*'

60. II. 'I ſuppoſe this æther pervades all 'groſs bodies, but yet ſo as to ſtand rarer in 'their pores than in free ſpaces, and ſo much 'the rarer as their pores are leſs.' *&c.* See Sir Iſaac *Newton*'s Letter to Mr. *Boyle*, written

in the Year 1678. Again,

61. *Secondly*, A moſt remarkable congruity appears between this Fluid and the common Air in almoſt every reſpect. The electrical Fluid is poſſeſſed of every property belonging to the common Air, both eſſential and accidental, (unleſs that of ponderoſity or gravity may be excepted †,) *viz.* rarity, ſubtilty, and elaſticity; is capable of dilatation and contraction; their particles, like thoſe of common Air, mutually repel and recede from each other, altho' in a much greater degree. But if the electrical fluid is deſtitute of one property belonging to the common Air, there are others belonging to the electrical fluid, not to be found, or at leaſt, not to be eaſily render'd ſenſible in common air ; e. g. the common air ſeems almoſt incapable of exhibiting any ſigns of light or fire ; nor can it be render'd viſible like electrical or pure air.

62. Another property ſeems common to both the electrical and the groſs air, which is this ; the groſs air contain'd in the ſenſible pores of the moſt rare hollow bodies, is capable of being heated by friction, as well as the electrical and more pure air contain'd in the mi-

† I have attempted to prove it by as accurate a balance as I cou'd well procure, but cou'd never perceive the leaſt gravitating Property belonging to it.

nuteſt

nutest pores of the most dense metals, but in a much less degree; and two sticks of the rarest dry hard wood, when rubb'd together will grow hot as well as metallic bodies, altho' as was before observ'd, in a much less degree. And the indefatigable *Boerhaave*, who had made a number of those experiments, informs us, that two gold plates may be rubb'd together till they grow so hot, as to be just at the point of melting: The pure Air or Fire, contain'd in the minute pores of the gold, seem much more capable of receiving an intense heat, than the more gross Air contain'd in the sensible pores of those rare, hollow, light bodies; and yet we find even *that* in those bodies, will grow so hot, by means of violent friction, as to be frequently kindled into an actual flame.

63. The Third and principal thing to be examin'd is, whether the electrical Air be endued with the same natural qualities and properties which are ascrib'd to Æther by Sir Isaac *Newton*, &c.

CHAP. III. PART I.

SECTION 64.

EXPERIMENTS, *which ſhew, that the* electrical Fluid *is endued with the two inherent or eſſential Properties of* Æther, *and in a moſt ſurpriſing degree, namely thoſe of extreme Rarity and extreme Elaſticity.*

THO' almoſt every Experiment either illuſtrates or demonſtrates the great Rarity and Elaſticity of the electrical Fluid; yet none more than the Leyden Experiment, which Shock and Exploſion are entirely owing to the alternate exertion of thoſe two properties, particularly in ſome of Dr. *Franklin*'s capital Experiments, of which the following is a Specimen.

65. That ingenious and approv'd Experimentaliſt, in order to examine into the ſurpriſing force of that moſt wonderful *Phænomena of Nature*, juſt diſcover'd, namely, the ELECTRICAL SUBTILE MEDIUM, had contriv'd a Device, which he call'd a magical Picture, by means of which he could ſtrike a hole thro' a

whole quire of paper, altho' a quire of paper is thought good armour againſt a Sword or even a Piſtol-Bullet. —— 2d. An electrical Jack, with which he could roaſt meat. This, when in motion, was loaded with 100 Spaniſh dollars, which ſeem'd not in the leaſt to retard its motion. —— 3d. A ſelf moving Wheel, which would make 50 turns in a minute, altho' above 50 Inches in circumference. —— 4th. By means of the force of the electrical fluid he could invert the Poles of the magnetic Needle; give a magnetiſm and polarity to Needles that had none before, and invert them at pleaſure. —— 5th. He could kill a Turkey of 10 pound weight; and had once nearly kill'd himſelf, of which we have the following narrative.

66. ' He inadvertently receiv'd the ſtroke ' of two of his large glaſs Jars through his arms ' and body, when they were very near fully ' charged. It ſeem'd to him an univerſal blow ' throughout the body from head to foot, and ' was follow'd by a violent quick trembling in ' the trunk, which went off gradually in a few ' ſeconds. It was ſome minutes before he could ' recollect his thoughts, ſo as to know what ' was the matter; for he did not ſee the flaſh, ' tho' his eye was on the Spot of the prime con- ' ductor, from whence it ſtruck the back of his ' hand; nor did he hear the crack, though ' the by-ſtanders ſaid it was a loud one; nor ' particularly feel the ſtroke on his hand, tho'

' he

'he afterwards found it had raiſed a a ſwell-
'ing there, of the bigneſs of half a Swan-ſhot,
'or Piſtol-bullet. His arms and the back of
'his neck felt ſomewhat numbed the remain-
'der of the evening, and his breaſt was ſore
'for a week after, as if it had been bruiſed.'

A full proof that bodies are replete with that ſubtile Medium, and that the Force of the ſhock is from the violent diſplacing of it in the pores of groſs bodies.

67. From what he had experienced of this elaſtic fire, he avers, that the greateſt known effects of Lightning might be exceeded by it, ſince, by his method he could obtain as great a quantity as he pleas'd.

68. Add to theſe, thoſe well known Experiments mention'd by the Rev. Mr. *Jones*. 'There is hardly a motion in nature', ſays that Rev. Author, 'which this fluid, when apply'd
'by a diligent Experimentaliſt is not capable
'of producing. It will give a *rectilinear* mo-
'tion, in all directions: It will produce the
'motions of *Rotation* and *Revolution*. It will
'keep a body ſuſpended at a certain diſtance
'in the air, without any viſible cauſe, and
'make it turn ſwiftly on its axis. It will ac-
'celerate vegetation, increaſe the motion of the
'blood in the arteries, raiſe water into tides;
'and in a word, will ſhew itſelf, as a natural
'Inſtrument, to be little leſs than ALL-SUF-
'FICIENT.'

69. *N. B.* Moſt of the above-mentioned

expe-

Experiments, when examined, appear to be perform'd by the two fore-mention'd natural properties of Æther, *viz.* exceſſive Rarity and Elaſticity, alternately exerting their contrary forces or qualities in deſtroying and reſtoring the equilibrium, and by that means generating motion.

70. Our two Engliſh Worthies, *viz.* Lord *Bacon*, and Sir Iſaac *Newton*, were ſtrongly poſſeſs'd of an opinion, that in the pores or interſtices of all groſs bodies was a certain ſubtile Medium in form of Air, but indefinitely more *rare* or *fine* than that, and as remarkably more *elaſtic* and *expanſive* or *ſpringy*. That this active MEDIUM in their pores, or SPIRIT as they termed it, was the cauſe of thoſe ſurpriſing affections and properties of motion which we ſo frequently behold in inert matter. A conciſe account of the opinion of the former I find in the Rev. and ingenious Mr. *Jones*'s Treatiſe on natural Philoſophy; and that of the latter in Sir *Iſaac*'s own Works: And firſt, of the former.

71. Mr. *Jones*, when treating of the doctrine of mechanical Cauſes, cites the following paſſages from Lord *Bacon*'s Works to illuſtrate his own opinion concerning ſuch *Cauſes*.

72. 'Certain it is' (ſays that noble Lord) 'that GOD worketh nothing in NATURE 'but by SECOND CAUSES, and if they would 'have it otherwiſe believed, it is mere *Impoſture*, 'as it were in favour towards God; and no-

'thing else but to offer to the Author of Truth 'the *unclean sacrifice* of a *Lye* *.'

73. 'It is observed by the same Author, 'with that brightness of Expression, so familiar 'to him on all occasions, that *Heat* and *Cold* 'are Nature's two *Hands*, whereby she chiefly 'worketh †. The nature of *Cold* in particular, 'he proposes as a thing worthy the Inquisition 'both for use and disclosure of CAUSES ‡. 'And he does not seem to have believed, that 'Cold is a mere privation of substance, but 'rather that it is active, and transitive into 'bodies adjacent, as well as Heat §. *Gilbert*, 'the magnetic Philosopher, having possess'd 'himself of an *attractio in distans*, had publish-'ed the doctrine of an absolute Vacuum, in 'the spaces between the cœlestial Orbs. The 'Lord *Bacon*, on the other hand, had formed 'to himself a Theory, according to which, all 'space is *filled* either with *aërial* or fiery nature ‖. 'He denied also that the pores or cavities of 'tangible bodies, admit of a Vacuum; but 'that they contain either *Air*, or a subtile '*Spirit* proper to their nature and disposition.' Of this Spirit he treats as of a *material* Cause, rejecting all those pretended Solutions as unmeaning and unphilosophical, which are de-

* Adv. of Learn. p. 5. † Nat. Hist. Cent. I. No. 69. ‡ ibid. § ibid.

‖ Theoria nostra negat vacuum illud coacervatum *Gilberti* inter globos sparsos, sed spatia vel *aëreâ* vel *flammeâ* naturâ *repleri*. *Thema cœli*.

duced

duced from *Virtues* or *Qualities* in matter, and with which the Schools in his time did very much abound. 'Whatsoever is invisible' (says he) 'either in respect of the body itself, or the 'smallness of the parts, is but little enquired. 'And yet, these are the things that GOVERN NATURE' principally; and without which 'you cannot make any true *Analysis*, and In-'dication of the *proceedings of Nature*. The 'Spirits, or Pneumaticals, that are *in* all tan-'gible bodies, are scarce known. Sometimes 'they take them for Vacuum; whereas they 'are the most active of Bodies. Sometimes 'they take them for Air; from which they 'differ as much as wine from water. Some-'times they will have them to be natural heat; 'whereas, some of them are cold. And some-'times they will have them to be the *Virtues* 'and *Qualities* of the tangible parts which they 'see; whereas they are things by themselves. 'And when they come to Plants and living 'Creatures, they call them Souls. And such 'superficial Speculations they have; like Pro-'spectives, that shew things inward, when they 'are but paintings. Neither is this a question 'of *Words*, but *infinitely material in Nature*. '—— As to the motions corporal, within the 'enclosures of bodies, whereby the *Effects* pass 'between the *Spirits* and the *tangible parts*, 'which are, rarefaction, colliquation, concoc-'tion, maturation, &c. they are not at all 'handled. But they are put off by the names

'of Virtues, and Natures, and Actions, and 'Paſſions, and ſuch other logical words. —— 'It is certain, that of all *Powers* in Nature, '*Heat* is the chief; both in the *Frame of Na*'*ture*, and the *Works of Art* *.' See Mr. *Jones*'s nat. Philoſ. p. 220.

74. Had Lord *Bacon* liv'd to ſee the Diſcoveries now made by means of Electricity, and found that there was in real fact ſuch an aërial inviſible Subſtance in the pores of bodies, as *He* and Sir Iſaac *Newton* had conjectur'd, and poſſeſs'd of the moſt wonderful properties, which he had before aſcrib'd to it; might we not reaſonably ſuppoſe he would have made ſome alteration in his plan, or at leaſt have lengthen'd his metaphor; and inſtead of comparing Heat and Cold to the two hands of nature, might probably have compar'd the electrical Fluid, either to nature's handmaid and chief agent; or elſe to what, he ſays, GOVERNS NATURE? And if heat and cold were two hands, he might poſſibly have concluded, that nature had more hands than two, and that the Rarity and Elaſticity of the ſubtile Medium were the moſt principal of all.

75. Sir Iſaac *Newton*'s Sentiments concerning ſuch a Medium in the pores of groſs bodies are contain'd in the concluding paragraph of his Principia, and are as follow: —— 'And 'now we might add ſomething concerning a

* Nat. Hiſt. Cent. I. No. 91. 99.

'certain

'certain most subtile Spirit, which pervades
' and lies hid in all gross bodies; by the force
' and action of which Spirit, the particles of
' bodies mutually attract one another at near
' distances, and cohere, if contiguous; and
' electric bodies operate to greater distances,
' as well repelling as attracting the neighbour-
' ing corpuscles; and light is emitted, reflect-
' ed, refracted, inflected, and heats bodies; and
' all sensation is excited, and the members of
' animal bodies move at the command of the
' Will, namely by the vibrations of this Spirit,
' mutually propagated along the solid filaments
' of the nerves, from the outward organs of
' sense to the brain, and from the brain into
' the muscles. But these are things that cannot
' be explain'd in few words, nor are we fur-
' nish'd with that sufficiency of experiments
' which is required to an accurate determina-
' tion and demonstration of the laws, by which
' this electric and elastic spirit operates.'——
That portentous Paragraph is now very clearly and literally fulfill'd, as the following Experiments most evidently prove.

76. Let any number of Persons lay each a finger on different parts of another Person, as on his face, back of his hand, legs, and other parts of his body, and let *him* at the same time draw off a spark from the prime conductor, &c. each of these Persons will feel a pulsation under his finger in contact, at the same instant; and if the room be a little darkened, a light ap-

appears under each of them.—— Or, *Secondly*, If they lay each a finger on different parts of a metallic body, and one of them at the ſame time draw off an electric ſpark from the prime conductor, *&c.* with the hand at liberty, every one of them will have the ſame ſenſation under his finger as before. Or if any number of perſons put each of them a finger in a veſſel of water of any ſize, and one of them draw off an electric ſpark from the excited apparatus, every perſon at the ſame inſtant will feel a pulſation at that part of the finger immerſed in the water.

77. *Thirdly.* If three, four, or more perſons communicate with each other in the following manner. —— Let the firſt perſon lay a finger on the face or back of the hand of the ſecond; the ſecond lay a finger of his other hand on the back of the hand of the third; in like manner the third on the back of the hand of the fourth, *&c.* and then if the firſt perſon, with a finger of his hand at liberty, or ever ſo long an iron rod or wire, draw off an electric ſpark, every one is affected thereby, and a ſenſation and light is perceived by each perſon at the part in contact. I myſelf have been the ſixth perſon from whence that ſmall eruption was made, and yet at the ſame time have been very ſenſible of the pulſation under my finger: Farther than that I never tried it. This, however, is certain, that were as many hundreds or thouſands ſupported on electric bodies, and to lay a

finger

finger lightly on each other as before directed, every one would experience the ſame ſenſation and light, provided the laſt perſon communicate with the floor at the time the firſt perſon draws off the ſpark.

78. Are not theſe manifeſt proofs, that the pores of bodies are replete with a ſubtile elaſtic fluid, ſimilar to the electrical fluid; and like that too, appears in form of fire? and alſo that the propenſity to preſerve an equilibrium among all its parts is ſuch, that if the leaſt rarefaction be made at any one ſingle part of a number of contiguous bodies (which may be effected, by only drawing off a ſingle ſpark) every part contained in thoſe bodies, on trial, ſeem ſenſible of it, be they ever ſo many, or ever ſo far extended, provided only they be ſupported with thoſe original electrics, and the fartheſt perſon ſtand on the floor.

79. *N. B.* It is to be remember'd, that in the foregoing experiments, neither of thoſe bodies on whom the experiments were made, were previouſly electris'd, which ſurely muſt be a clear proof that it exiſts in thoſe bodies at all times, as alſo of its extreme elaſticity.

80. If any ingenuous and unprejudic'd perſon, after ſeeing thoſe experiments, can ſtill reaſonably doubt, whether there be a ſubtile, active agent in the pores of thoſe bodies; to put it paſt diſpute, and to prove that it is retain'd in bodies, by means of the repellancy and preſſure of the incumbent atmoſphere,

81 Let a clear glaſs jar of water be put under the Receiver of an Air-pump, where the exhauſtion is no ſooner begun, but the little expanſive particles are plainly ſeen to riſe and eſcape thro' the body of the water to the ſurface; and this, all the time of the exhauſtion.

82. 'From fermented liquors they appear 'in much greater plenty, and frequently re-'main viſible, after they have quitted the li-'quor, and riſe like ſteam, as may be proved 'by white wine, and many other tranſparent 'liquors, that have undergone any conſiderable 'degree of fermentation.——From groſs and 'weaker liquors, that contain leſs of this ſpirit 'and more of the groſs air, it aſcends in larger 'bubbles; which, if the liquor have any de-'gree of tenacity, as ſmall beer, *&c.* it remains 'at the top in a great number of bubbles, in 'form of froth: All liquors thus robb'd of this 'ſpirit, become vapid and dead ‖.'

83. *Secondly.* 'In like manner it is obſerved 'to eſcape from many ſolid bodies, when in 'vacuo, and immerged in water, particularly 'Salt-petre, if the liquor, wherein it is im-'merged, be a ſtrong clear Aſh-lye §.'

84. I purpos'd by way of order or method, after proving the exiſtence of ſuch an agent in the pores of bodies, to ſhew how a fluid ſo ſubtile and elaſtic could be retained there; but ſince the ſame thing was effectually proved by

‖ Clare's Fluids, p. 205. § ibid. 253.

the

the removal of the air, that work is entirely ſuperſeded. Thoſe experiments on the Air-pump as effectually prove the cauſe of its retenſion in bodies, as its exiſtence there; ſince the repelling air is no ſooner remov'd, but the little particles are ſeen to eſcape from their Cells.

85. The explanation of the next principal or chief accidental property alſo will, for the ſame reaſon, be much facilitated thereby, namely, How a fluid ſo extremely ſubtile and elaſtic could be collected, and retained on the prime conductor, *&c.* ——— But excluſive of the foregoing auxiliaries or aids afforded by means of the air-pump, Reaſon alone muſt be ſufficient to inform the ingenuous and unprejudiced enquirer after truth, that ſince ſo ſubtile and elaſtic a fluid is undeniably condenſed and retained in the open air, the air muſt neceſſarily be the only agent that retains it; for as a propenſity to maintain an equilibrium among all its parts is a well known property of an elaſtic fluid, nothing but the air can poſſibly be a barrier to it, (when accumulated on bodies) ſufficient to confine it long enough to make the proper experiments.

Sir *Iſaac* informs us, that the air produc'd from hard bodies is the moſt elaſtic, which is natural to ſuppoſe; for by reaſon of the minuteneſs of the pores of thoſe hard, denſe and ponderous bodies (ſuppoſe metals) nothing but this ſubtile elaſtic fluid is capable of occupy-

ing or poſſeſſing them ; this, when freed from its confinement, neceſſarily remains much more elaſtic than the ſame quantity of the common air.

86. But to obviate a ſlight objection, which may poſſibly be made to thoſe experiments on the Air-pump, viz. *Thoſe Experiments prove no more than that Air is contained in groſs bodies, both ſolid and fluid, which wanted no proof in this place ; ſince almoſt every one who has made Experiments with the Air-pump is well aſſured of it long ago.*

87. I anſwer : Though it is ſo well known to be Air ; yet it is ſuch air, that moſt, who have hitherto reaſon'd on it, ſcarce know what to make of, or what to call it. They, finding it ſo different from common air, call it factitious or artificial air, generated air, counterfeit air, to diſtinguiſh it from any natural production †. And they may find too, if they ſink a piece of braſs in a glaſs of clean water, and place it under the receiver, and exhauſt the external air, the pure electrical air contain'd in it, ſoon begins to ſhew itſelf ; and if the operation continues, almoſt the whole ſurface of the braſs will be covered with little pearly bubbles which riſe out of it * ; conſequently the braſs is pervious by this pure air, i. e.

† See *Bailey*'s Dictionary, under the Word Factitious.
* See Mr. *Martin*'s 1ſt. Vol. of *Ladies Philoſophy*, p. 350.

Æther ;

Æther; but very far from being ſo by the common air; ſo far from it, that even the barrels of the common condenſing engine are generally made of braſs to confine the air, altho' it be ſometimes ſo extremely condenſed withinſide of it. The chamber of the wind-gun alſo.——If in the foregoing experiment it had been common air, and yet find ſo eaſy a paſſage out of the braſs, when only the weight of the atmoſphere was taken off, how much eaſier would it pervade the braſs barrel of the condenſer or wind-gun, when the elaſticity was then perhaps ten times, or much more increaſed?

88. As to counterfeit air, or generated air, ſince ſuch terms could never be render'd intelligible, nor has it ever been explain'd, how, or in what manner ſuch air was generated, no wonder if many have been much puzzled for a meaning.

89. But fallacious as theſe may be, nothing can illuſtrate and confirm any thing much more clearly than this kind of reaſoning does, that Sir *Iſaac*'s poſition was juſt and true concerning his Æther in the pores of groſs bodies, and conſequently well founded: And I may add too, that the following method of producing artificial air muſt be as great an illuſtration and confirmation of the juſtneſs of the 1ſt. and 4th. Articles [or Heads] of my Theory; and that they are true, or at leaſt, that they are founded on reaſon; particularly when we conſider with what

facility we can, by analyſing groſs bodies, and reducing them to their *firſt* Principles or original chaotic form, generate ſuch artificial air, that ſhall in almoſt every reſpect reſemble the common air: Nothing, I ſay, can illuſtrate and confirm any thing much more clearly than this does, that the pores of groſs bodies are replete with ſuch a primary air.

90. The method I mean, is that made uſe of by the renown'd Dr. *Hales* in his vegetable Statics. He, by means of menſtruums, fermentations, heat, diſtillation, *&c.* diſſolv'd and analyſed bodies ſo nearly to their *firſt* Principles, that the primary air, originally in their pores, riſing in diſtillation, *&c.* along with the terreſtrial particles, were ſo combin'd with each other, as to form a conſiſtence which reſembled the common air in almoſt every reſpect, unleſs that of the vivifying and ſalutary qualities; *his* artificial air being for the moſt part found noxious, and very ſoon fatal to animals when put into it.

91. What conducted him to ſuch experiments and reaſoning ſhould ſeem to be a miſtaken notion which he had conceiv'd, *viz.* that the elements were of a very mutable nature, and eaſily chang'd and metamorphos'd from one to another; and that the air in particular was endued with a double capacity, i. e. of changing *pro re natâ*, as he expreſſes it, from a ſtrongly attracting fix'd ſtate, to a permanent and vaſtly elaſtic one, and *vice verſâ*.

92.

92. One thing in particular is very well worthy of obſervation, which ſeems to illuſtrate Sir *Iſaac's* doctrine, concerning the wonderful elaſticity of the primary Air or Æther in the pores of groſs bodies. What I mean is, that the ſame pure æther, which was contain'd in the pores of a body not exceeding a cubical Inch, ſhould yet (when ſet at liberty and expanded by heat, and then mixing with the terreſtrial corpuſcles, and the whole reduc'd down to the temper of the groſs ſecondary air) be ſufficient to form 645 times that quantity, which was the caſe of the artificial air the Dr. obtain'd from the human calculus.

93. Probably if theſe kinds of experiments were duly examin'd, a tolerably juſt proportion might be obtain'd between the different purity, different rarity, and different elaſticity of the primary and ſecondary air; the Dr. being ignorant of ſuch an elaſtic medium in the pores of bodies as is ſince diſcover'd, falſe concluſions from ſuch kinds of experiments as thoſe were inevitable. How ingenious were the Doctor's concluſions; and yet how falſe do they appear to be when view'd in a different light! This will be more clearly proved at the beginning of the Miſcellany, or Third Part.

94. There is one thing more of great weight, *a Property* in bodies not yet mentioned, which is (to me at leaſt) as great a confirmation of the exiſtence of a finer elaſtic fluid than common air in the pores of denſe bodies, as any-

any one thing can be, namely, that Sound is convey'd or propagated through them with the greateſt facility; and not only propagated, but magnified alſo. Is not the cauſe of this Phænomenon, the great elaſticity of the pure air contained in thoſe bodies? Since it is found by experiment, that Sounds in general are magnified and propagated to greater diſtances, in proportion, as the elaſticity of the common air is increaſed †.

95. Mr. *Clare* in his fluids has collected ſeveral facts (moſt of which are well known) to prove the propagation and increaſe of Sounds through denſe bodies; but he accounts for the Phænomenon, by ſuppoſing them to be propagated by means of the vibrations of the parts of thoſe *ſolid Bodies* themſelves; and gives us the following accounts to prove it: And firſt, of a Perſon who was born Deaf.

96. 'I have ſeen a Perſon,' ſaith he, 'that 'was born deaf, (and probably will always con'tinue ſo,) when he held the end of a Violin 'between his Teeth on which another play'd, 'rejoice very much, as being that way ſenſible 'of the Muſic. This could only be communi'cated to his perception, by the vibration of the 'ſolid parts, the bones of his head, communi'cated thither by thoſe of the Inſtrument.'

97. 'And this experiment any one may 'make, by ſtopping his ears with his fingers ſo

† See Mr. *Haukeſbee*'s Experiments, p. 125.

'cloſe,

'close, that he cannot hear an Inſtrument that 'ſhall be play'd on : Let him then lean his 'head, either againſt the Inſtrument, or a long 'ſtick that touches that Inſtrument, and he 'will diſtinctly perceive every Note that is 'play'd.'

98. 'This is one way the Mariners take to 'diſcover whereabouts the Leak in a Ship is, 'when not eaſily found, *viz.* They take a ſtaff, 'and holding one end of it tight to their ear, 'they apply the other ſucceſſively to the ſe-'veral parts of the ſides of the ſhip, till they 'diſtinctly hear, where it is the water ruſhes 'in, tho' the noiſe be much too inconſiderable 'to be found by the ear alone. And 'twould 'be very difficult to remove the ballaſt and 'ſtowage of this bulky machine to attempt it 'any other way.'

99. 'It is a common experiment for two 'perſons, placed at each end of an extended 'cable or a ſtick of timber of any length, one 'of them to hear a ſcratch made by a pencil, 'or a ſmall fillip with the finger, (from the 'elaſticity and continuity of the parts of thoſe 'bodies) made by the other. The centinels 'of the advanced guard are order'd to lie on 'their bellies with their ear to the ground, 'that the earlieſt notice of a motion of the 'enemy (to prevent a ſurpriſe) this way, may 'be had, from the ſound communicated by 'the earth. And jealous Princes have ſome-'times had pipes laid from the council to the

'cabinet,

'cabinet, whereby they have become maſters 'of the conference, convey'd to them by the 'elaſtic fluid enclos'd therein.' Mr. *Clare's* Fluids. p. 296. 297.

100. *Remark.* The Muſic, he tells us, could be communicated to the conception of the deaf man, only by the vibration of the *ſolid parts,* the bones of his head, and communicated thither by means of the Inſtrument.

101. How natural ſuch a method of accounting for the propagation of ſound through ſolid bodies might appear to Mr. *Clare,* who had rejected the exiſtence of Sir Iſaac *Newton's* ſubtile Medium (not only in the pores of bodies, but of Æther in general ‡) I cannot determine; but ſince ſuch a ſubtile Medium is ſo clearly diſcover'd in denſe bodies, I ſhall appeal to the judicious and unprejudic'd Reader, to determine which he thinks the moſt eaſy and natural method to account for the propagation of thoſe ſounds: Whether by means of the vibration of the *ſolid inflexible parts* of the teeth, the bones of the head, and thoſe of the timber log, which, as he ſays, may be of any length, or the vibrations of the unelaſtic earth, from the camp to the centinel's ear on the ground? Or, whether ſuch ſounds are propagated by the vibrations of the elaſtic fluid contained in the bodies? But ſure I am, ſuch

‡ See Mr. *Clare's* definition of Æther in his Gloſſary. *Æther. An imaginary Fluid, fine and ſubtile.*

a method of accounting for thofe effects, by vibrating inflexible folids, muft appear uncouth to thofe, who have been accuftom'd to believe, that the pores of denfe bodies are replete with a fubtile elaftic fluid, in the manner Sir Ifaac *Newton* affirmed, and as verified by electrical experiments *.

102. Could the matter be put to the teft of a proper trial, the velocity of founds, by means of the medium contained in thofe bodies, I am fully perfuaded would appear equally inftantaneous as the velocity of this fluid is found to be in electrical experiments.

103. Quære. Whether it be not unnatural to fuppofe fuch an extraordinary vibration of the parts of folid bodies, when at the fame time, neither reafon or any one fenfe informs us of any fuch motion in their parts.

104. *N. B.* A fmooth furface feems neceffary to the body that propagates the found; but the chief requifite is, moft probably, the

* To fhew I am not fingular in fuppofing that Sounds are propagated through denfe bodies by means of an elaftic fluid exifting in their pores, I fhall cite a quotation of Mr *Jones's* taken from *Seneca*, 'That a Medium muft be conceal'd within 'the moft folid bodies; becaufe found would not 'otherwife be *tranfmitted through them* as it moft 'certainly is.'

This is one of Du *Hamel's* arguments for a fubtile Æther. See Mr. *Jones's* Firft Principles of natural Philofophy. p. 213.

ſolidity of the body, whoſe pores are ſo minute, as to admit of the more pure and more elaſtic air only.

Mr. *Clare* has a great opinion of the former, as appears by the following narrative.

105. ' It might ſeem incredible,' ſaith he, ' that the voice of a Man might be diſtinctly ' heard at the diſtance of ten or twelve miles: ' But a Gentleman of great veracity, who liv'd ' ſome years at *Gibraltar* affirms, that he has ' at *Old-Gibraltar* heard the Watch-word of ' the night, viz. *All's Well*, given by the cen- ' tinels to the patrole, as they paſſed all along ' the Ramparts of *New-Gibraltar*, in a ſtill ſe- ' rene night, when the water was perfectly ' ſmooth, as plainly and diſtinctly, as the Offi- ' cers who walked the round, or himſelf (had ' he been upon the Rampart) could have done. ' This is a ſufficient proof of the ſervice it is ' to places of hearing, that the ſurfaces of things ' ſhould be in them as ſmooth as poſſible.' Mr. *Clare's* Fluids. p. 303.

106. Since the foregoing experiments ſo clearly prove the exiſtence of a ſubtile fluid in the pores of groſs bodies, and in which there appears, not only a remarkable elaſticity, but alſo a continuity of its parts: Can it then be any longer doubted, whether the motion of it in the experiments be propagated through the internal parts of the ſeveral bodies, or whether over and along their ſurfaces, as has been ſug- geſted? But if that can ſtill be doubted; let

a wire of any imaginary length be ſupported with ſilken ſtrings through ever ſo many rooms, and back again, one end of which to communicate with the prime conductor; by this means, when the wheel is in motion, the whole length of the wire will be electriſed, i. e. the active fluid will be accumulated on every part, as may be eaſily proved by drawing ſparks from it, and by ſeeing how briſkly light bodies are agitated, when placed near to any part of it on a plate: But if any part of the wire be made to communicate with the floor either directly or indirectly, all the Phænomena ſeem then at an end. To illuſtrate this: Let a Perſon take hold of the inſulated wire, even at the remoteſt part from the Machine, and all the afore-mentioned accumulation vaniſhes; the light bodies all lie ſtill on the plate, nor can any ſpark be drawn from any part of the Apparatus: A Perſon therefore unacquainted with thoſe experiments would think all was at an end; whereas the fluid is all the time ſwiftly paſſing into the earth through the internal ſubſtance of the wire, and through the Perſon who holds it at the end. —— To prove this: Let the ſupported wire be clipp'd aſunder at parts where it is ſo ſupported, that the two ends may not drop from each other, and the Fire will plainly appear between every ſuch ſeparation, even though the experiment were made at noon day: Then let the Perſon releaſe the end of the wire, or elſe ſtep on the Reſin-cake

(either of which cuts off the communication with the earth) and then the accumulation again takes place; the light bodies alſo on the plate will be in motion as before, but no Fire appears at the ſeparations; for *that* Phænomenon never happens, unleſs the part of the wire beyond the ſeparations communicates with the floor.

107. Another effectual method to prove that it moves through the internal parts of nonelectrical bodies, may be the following:

108. Let Four Corks be fitted to a glaſs Tube as A B, having a wire through each of them; and two of thoſe Corks as C D, with their wires g h, and k l, be thruſt in towards the middle of the Tube, ſo far, that the two Loops of the wires h and k, which project beyond the ends of the Corks, may come near each other in the middle of the Tube. After which, let the two ends of the Tube E F, be filled with water, and then ſtopped with the other two Corks G and H. Pl. II. Fig. 1.

109. Let the glaſs thus prepared be made a part of the forementioned Line of inſulated wires, by taking out a part of the wire, and putting the tube in its ſtead: This line thus compounded of the prime conductor, the divided wires and the water-tube, will ſtill anſwer the ſame ends as before in every reſpect. A Perſon ſtanding on the Reſin and communicating with the extremity or other parts of the wire is electriſed in the ſame manner as at other

times: The fire appears at every ſeparation of the wire as before, if a ſpark be drawn from the electriſed Perſon, or the wire with which he communicates.

110. And in a word, the propenſity of this elaſtic fluid to maintain an equilibrium among all its parts is ſo amazingly great, that if a ſpark be drawn off, tho' from the moſt diſtant part, a correſponding ſpark appears, not only at each ſeparation of the wires, but alſo between the two wires in the middle of the water-tube.

111. Having thus far conſider'd the great ſubtilty and elaſticity of the electrical Medium, I ſhall in the following Chapter explain more particularly the natural effect of an elaſtic fluid, *viz.* that of its expanding.

CHAP. IV. PART I.

SECTION 112.

INTUMESCENCE, &c. *of an* elaſtic Fluid.

INTUMESCENCE is that Property of an elaſtic Fluid, of expanding, ſwelling, and conſtant endeavour of extending itſelf to larger Dimenſions.

113. 'This will be the better underſtood, if 'with Mr. *Boyle*, we conceive the primary Par-' ticles,

is continued; but when that is at an End, the accumulation lessens, and the sides of the Triangle contract, gently and gradually, till the Corks meet. Balls of Lead, if suspended to such Threads, will when electris'd repel each other in the same manner, and to as great a Distance, if their Threads are sufficiently lengthened†.

120. Fourthly. *That the primary and secondary Air mutually repel each other.*

This is put past dispute from the effects of the following

EXPERIMENT.

121. If a piece of Wire of about Six Inches in length be pointed at each end, and those ends turn'd different ways, as in Pl. II. fig. 2. and that wire be suspended on the point of a Needle, erected for that purpose on the prime Conductor of the Machine, in the manner a magnetic Needle is suspended; this pois'd Wire is no sooner electris'd, than the fiery Particles begin to be hurried off as usual at the Points; those

† 'Every particle of Matter electrified is mutually repelled by every other neighbouring particle equally electrified. Thus, the stream of a fountain, naturally dense and continual, when electrified, will separate and spread in the form of a Brush, every drop (or particle of the Water thus electrified) endeavouring to recede from every other particle. But on taking away that electrical Fire, they close again,' like the cork Balls. See Mr. *Franklin's* Letters on Electricity. p. 37. 2d. Edition.

elastic

elaſtic Particles ſtriking the elaſtic Air mutually repel, and conſequently the repell'd points of the Wire will give way, and fly back; which Motion of the Wire will increaſe, till it becomes as rapid as the Flyers of a Jack, ſo that when the Room is darken'd, a circle of Fire is formed*.

Since then the primary and ſecondary air ſo manifeſtly repel each other, can it be reaſonably doubted, whether the retenſion of the former, in the experiments, which accumulates on groſs bodies (inſtead of diſperſing) be from the effect of the repelling ſpring of the latter ſurrounding it? for otherwiſe, by means of its great Elaſticity and Subtilty, it muſt neceſſarily eſcape, as ſoon and as faſt as collected. But the elaſticity of the ætherial particles contain'd in it, ſuffers not the includ-

* The fiery particles, iſſuing from pointed bodies when electris'd, have an exceeding lively reſemblance of the fiery particles iſſuing from the mouth of a ſquib or ſerpent, when kindled; which diverge and recede from each other, in the ſame manner with thoſe of the artificial fire-work, (particularly when they are faſten'd to the circumference of a wheel,) and each of thoſe appears to act from the very ſame principle; tho' it muſt indeed be allow'd, that the ſmallneſs of the aperture of a ſerpent, thro' which the fiery particles force their way, very much accelerates the motion on the wheel. The elaſtic particles of each one, ſtriking againſt the elaſtic air, recoil, and are repell'd back.

ed primary air to eſcape freely to gain its enlargement. Freely I ſay, for it ſeems perpetually, tho' inſenſibly eſcaping; becauſe, a conſtant Attrition of the revolving glaſs is abſolutely neceſſary to keep it to its full height: When once that attrition is diſcontinued, the accumulation on the prime conductor, &c. is almoſt inſtantly at an end; conſequently it was before *that*, conſtantly eſcaping.———This doctrine concerning its retention when accumulated ſeems likewiſe to be confirmed, by obſerving, that when the barometer is higheſt, and the air conſequently moſt elaſtic, the accumulation is then greateſt, and continues the longeſt after the attrition is over.———But although theſe conſiderations alone ſufficiently evince, that the elaſticity of the circumjacent air is the only reaſon why the electrical æther in thoſe experiments is ſo retained, as to accumulate on the included bodies; yet many others might be produc'd to prove it were it neceſſary, and were it poſſible to conceive any other agent ſo ready at hand, and ſo capable of confining it down to the electris'd body.

122. But as Mr. *Haukſbee* obſerves on another occaſion, 'the beſt proof that can 'be given of the truth of any hypotheſis, is, 'that the experiments made for that end do 'all of them and every way agree: That 'trying Nature on one ſide, and on the other, 'yet every way (if the hypotheſis be right) 'ſhe ſtill confeſſes the ſame thing. Thus with

'reſpect

'respect to the nature of sounds; it is demon-'strable, that the air is a proper vehicle or me-'dium for the propagation of them; because 'sounds do not only *lessen and grow weaker*, 'according to the degrees of the Air's rare-'faction; but also become more *intense and* '*strong*, according to the degrees of its con-'densation.' Mr. *Hauksbee*'s Exp. p. 88. 2d. Edition.

By way of illustration therefore, or rather to put it beyond dispute, I shall proceed to shew that the former arguments are just, concerning the retension of the electrical fluid by means of the repelling spring of the surrounding air; and that the same thing is confirmed by the removal of it.

123. Provide a proper conductor to the inside of a glass vessel, and exhaust the air, then electrise that conductor, and immediately a light appears in the vacuum.'

124. 'On the bottom of a tall frame of 'wood are two cups of glass placed, partly 'fill'd with mercury, in which are immersed 'the two ends of a long incurvated glass tube, 'in each part whereof, the quicksilver rises 'above that in the bason, to the height of a-'bout 30 Inches; and all the internal part of 'the tube above the quicksilver, is a vacuum, 'or a space, as void of air, as can be made, 'perhaps, by art.——I lay a wire from the 'barrel (or prime conductor of the machine,) 'to the mercury in one of the glasses, which

'conducts the electricity to the tube.——The 'globe is whirl'd round, and behold! How 'quick the lightning flies from the mercury 'into the *vacuum* of the tube?—In that, how 'strong, how vivid, how sensibly, and how 'quick it moves thro' that long space of the 'tube!——Ascending in one part, running 'over the top, and down the other leg of the 'tube, in an apparent rivulet of fire.——— 'When I put my finger on the barrel, to in-'tercept the fluid, it flows no longer in the 'tube.——My finger removed, the torrent of 'fire rushes on, as before, with an unequal, un-'dulating kind of motion†.' ——In that experiment, the conductor to the vacuum, was the column of quicksilver.

125. An experiment of this kind may be commodiously made with the exhausted glass receiver, on the air-pump, where the conductor to the *vacuum* may be the wire, which is made use of to drop the guinea and feather both at once. And though art may double or triple the quantity and power of electricity, by combining together the action of several globes under attrition, at once, in the same machine; yet, to what degree soever it be increased, 'twill be in vain to attempt to turn such streams of light into a vessel that is already filled with air.'

† See Mr. *Martin*'s Gent. and Ladies Philosophy, Vol. 1st. p. 321.

126.

126. But in many other experiments, if that grand obſtacle (the *air*) be removed, even the glaſs it ſelf ſeems as eaſily pervaded as other groſs bodies, and the condenſed æther, by means of its ſubtilty and great propenſity to obtain an equilibrium, inſtantly eſcapes through the glaſs into the vacuum, as freely as if nothing were in the way. For,

127. ' Exhauſt a glaſs globe, and whirl it ' round briſkly on its axis with the palm of a ' hand applied to the ſurface, and preſently ' you have a light in the glaſs, ſo great, that a ' large print may without much difficulty be ' read by it.' See Mr. *Haukſbee*, p. 45.

128. ' I took a *long glaſs*, (ſaid he) whoſe ' air was exhauſted, and which had lain by in ' that ſtate above ſix months. After I had ' rubb'd this glaſs a little with my hand, to ' clear it of all moiſture on the ſurface, I held ' it over the *unexhauſted globe*, which was then ' in motion, and at the ſame time alſo I gave ' it (viz. the unexhauſted globe) an attrition ' with my hand; upon which there were im- ' mediately large and ſurpriſing *flaſhes of light* ' produced in the long glaſs, though it neither ' touched the moving globe, nor was provok'd ' it ſelf by any immediate *ſenſible* attrition.' Mr. *Haukſbee*, p. 80.

129. Again, at p. 83. of the ſame Author. ' I took a large receiver, within the body of ' which I fix'd another. Their axes were pa- ' rallel to the horizon. The outward ſurface

of

'of the inner glaſs was at leaſt an inch diſ-
'tant from the inner ſurface of the outward
'one. Each glaſs was turned by its own par-
'ticular wheel, ſo that either both, or but one
'might turn at the ſame time. Before the
'glaſſes were thus adapted to each other, the
'innermoſt was exhauſted of its air; and then
'being plac'd in the machine, I order'd that
'wheel only to be turn'd which gave motion
'to the great glaſs; the effect was, that a light
'appeared and ſpread it ſelf in numerous bran-
'ches all over.———This done, I caus'd the
'other wheel to be turn'd, viz. that which
'gave motion to the included glaſs; and then
'the light became much more conſiderable,
'and, I think, the greateſt that has yet been
'produced in any experiment made on this
'ſubject'.

130. Farther on.—— 'I obſerved farther,
'that tho' the effluvia ſeemed to be equally
'diſtributed on the outward ſurface of the
'inward moving glaſs; yet the light appeared
'moſt vigorouſly on that ſide of it next the
'attrition. And when either of the glaſſes
'was at reſt, the other continuing in motion,
'(I ſay *either*; for upon trial I found very
'little difference either way;) the appearance
'of the light would remain a conſiderable time
'*within* the exhauſted glaſs, till the effluvia
'of the other were no longer capable of acting,
'with a force upon it, requiſite to produce
'the effect'.

131.

131. 'Twas not a little surprising also to 'observe, that after both glasses had been in 'motion for some time, and the hand applied 'during that time to the surface of the outer 'one, that then, the motions of both ceasing, 'and no light appearing at all, if I did but ap-'proach my hand again near the surface of 'the outward glass, there would be flashes of 'light (like lightning) produced in the inward 'glass; just as if the effluvia from the outer 'glass had been pushed with more force upon 'it by means of the approaching hand.'

132. From the effects of all these experiments and many others it indisputably appears, that the *common air* is a much stronger barrier for securing and confining the *more pure air*, than the *glass* of the tube or globe, by finding how readily it pervades the latter, to escape from the pressure of the former, when the air is exhausted out of the glass.

133. Hence also it evidently appears, that the sole cause of the whole electrical Phænomenon depends on this principle, namely, *that the primary air or æther is retained in the experiments by means of the repelling spring of the circumambient secondary air*, which confines it down on every side to the gross body on which it is accumulated.

COROLLARY.

134. Hence it appears, that Sir Isaac *Newton's* position concerning the extreme rarity and

and extreme elaſticity of æther was juſt; ſince it is ſo clearly confirm'd from the effects of the foregoing experiments, where we find ſo great an elaſticity in the electrical fluid accumulated on the prime conductor, *&c.* as to buoy up, and bear off the common air; and by that means a vacuum is form'd in thoſe limits, or what is equivalent to it, the æther which occupies that ſpace, being according to Sir *Iſaac*'s calculation 700000 times more rare than the common air, which it has by means of its ſuperior elaſticity diſplac'd: But yet the ſame ſurrounding air retains it there, ſo as not to ſuffer it to make a free eſcape.

The want of this knowledge render'd almoſt every thing elſe in electricity, dark and myſterious.

135. Tho' the rarity, elaſticity, and ſubtilty of æther ſo much exceeds the ſame properties in common air, and muſt therefore appear moſt wonderful; yet how much more ſo muſt it appear when we conſider the exceeding expanſity and ſubtilty of the common air, which ſo freely inſinuates and pervades the pores of various compacted bodies?——By means of the ſpring and preſſure of the atmoſphere, water is protruded in a vacuum to a conſiderable height, as in a common pump, not only while the mouth of the well is open, but after it is covered ever ſo firmly with boards and earth; for even then the artificer ſeldom finds it neceſſary to uſe any precaution, ſo as to leave a

vent-

vent-hole through ſuch covering, for admiſſion of the air. again,

138. The elaſtic ſpring and expanſive force of the common air at the ſurface of the earth is almoſt incredible.——Sir Iſaac *Newton* informs us, he had found by a calculation, ‘ that if a ſphere of *our* air, of but one Inch ‘ in diameter, were equally rarified with the ‘ ſame air at the height of one ſemi-diameter ‘ of the earth, from the earth's ſurface, it ‘ would fill all the regions of the planets, to ‘ the orb of ſaturn, and far beyond it.’ Princip. Lib. 3d. p. 366.

137. 'Tis preſum'd that the force of thoſe evidences already produced is abundantly ſufficient to ſerve as a ſpecimen of the juſtneſs of Sir Iſaac *Newton's* poſition, concerning a ſubtile medium exiſting in the pores of groſs bodies, though many more might be added to corroborate and confirm it were they neceſſary, I ſhall therefore (as there appear no *material* evidences to invalidate or ſet aſide thoſe already produced) enquire yet more particularly what he has aſſerted concerning it.

138. In his optics we find him making an ingenious experiment to prove the exiſtence of ſuch a ſubtile and expanſive medium in a ſpace void of air, and then appeals to the candid and judicious reader, to determine, whether it muſt not be neceſſarily univerſal, and *expanded thro' all the Heavens*. See Quære. 18.

139. He next proceeds to inveſtigate its na-

tural, or essential properties, and makes such a notable discovery, which was scarce ever attempted before, at least with any success, namely, that the same æther which was so much like air, was 700000 times more fine or rare, and yet 700000 times more elastic than that. That I may not marr the sense of his reasoning, I shall cite the whole passage, in the following chapter, and conclude the present with a few remarks on the most predominant *accidental* quality of æther, viz. that of *subtilty*.

140. Now subtilty is that property of æther which by means of the rarity, or exceeding fineness of its first elements or corpuscles, in conjunction with its elasticity, seems necessarily as it were, to pervade or insinuate into the intersticial vacuities of gross bodies, to escape from the incumbent pressure, and repelling spring of the surrounding atmosphere*; subtilty therefore, in strictness, is by no means so properly a natural quality, or essential property, as either rarity or elasticity.—— As a consequence then of this property of subtilty, *&c.* we find it in the pores of all gross bodies, particularly those term'd non-electrics, whether of metals, water, or animals; or vegetables pro-

* To all minute vacuums (if the term be allowed) i. e. the pores contained in the most dense and compacted bodies, provided they are non-electrics, and those whose pores are so small that the gross air is excluded, and where nothing but the same æther, or primary air can insinuate.

vided

vided they are green and replete with Juices: Thofe being the only bodies to which it efcapes the moft freely, fince it is not repell'd by them: Any of thofe kinds of bodies, when perfectly infulated or cut off from all communication with the earth by means of filken ftrings, or other original electrics, are thofe to which it efcapes and accumulates all the time the machine is in motion, if any of thofe infulated bodies are within the reach of it; accumulates I fay, the pores feeming always fo replete with the fame electrical principle, as if incapable of receiving any addition, as will more fully appear farther on.

N. B. The pores of all other bodies even thofe that are the moft perfect electrics *per fe*, appear as replete with this principle, as thofe term'd non-electrics; but in thofe bodies it is more firmly fix'd.

CHAP. V. PART I.

SECTION 141.

Farther Accounts of the Wonderful ESSENTIAL *Properties of* Æther.

I *Come now to confider the Rarity, or Thinnefs, and the Elafticity, or Springinefs of Æther, with the Proportion obferved by Sir Ifaac* Newton *between*

these Properties in that, and the same Properties in common Air, and the means by which he investigated that Proportion.

142. *First.* That the medium which propagates Sound is the common air; and consequently, that the finer and thinner elastic air or æther beyond the atmosphere is the medium which conveys or propagates light from the heavenly bodies.

143. *Secondly.* That sound is observed to move the space of an hundred miles, in much about the same space of time, that light moves from the Sun to the Earth, which distance Sir *Isaac* computed at 70 millions of miles; therefore as 100 is to 1, so is 70000000 of miles, to 700000 miles: From thence he infers, that not only the different velocities of light and sound, are in the proportion of 700000 to 1, but the density, rarity, and elasticity, are in the same proportion also. See his own words.

144. 'Sounds move about 1140 english 'feet in a second minute of time, and in seven 'or eight minutes of time they move about 'one hundred english miles. Light moves 'from the Sun to us in about seven or eight 'minutes of time, which distance is about '70000000 english miles, supposing the horizontal parallax of the sun to be about 12''. 'And the vibrations or pulses of this medium, 'that they may cause the alternate fits of easy 'transmission and easy reflexion, must be swifter than light, and by consequence, above

700000

'700000 times swifter than sounds; and 'therefore the elastic force of this medium, 'in proportion to its density, must be above '700000 multiplied by 700000, that is, above '490000000000 times greater than the elastic 'force of the Air is in proportion to its den-'sity. For the velocities of the pulses of elastic 'mediums are in a subduplicate ratio of the 'Elasticities and the Rarities of the Mediums 'taken together.' *Optics.* Quære 21.

145. The latter part of the above Quære, and the next following it, containing what may serve to illustrate the forementioned reasoning concerning the rarity of the æther or pure air, as also its expansive force, are as follow:

146. 'As Attraction is stronger in small 'Magnets than in great ones, in proportion to 'their bulk; and Gravity is greater in the sur-'faces of small Planets than in those of great 'ones, in proportion to their bulk; and small 'bodies are agitated much more by electric 'attraction than great ones: So the smallness 'of the rays of light may contribute very much 'to the power of the agent by which they are 'refracted. And so if any one should suppose, 'that æther (like our air) may contain parti-'cles which endeavour to recede from one 'another *(for I do not know what this Æther 'is)* and that its particles are exceedingly 'smaller than those of air, or even than those 'of light: The exceeding smallness of its par-'ticles may contribute to the greatness of the

'force

'force by which thoſe particles may recede 'from one another, and thereby make that 'medium exceedingly more rare and elaſtic 'than air, and by conſequence exceedingly leſs 'able to reſiſt the motions of projectiles, and 'exceedingly more able to preſs upon groſs 'bodies, by endeavouring to expand itſelf.

147. 'Qu. 22. May not Planets and Co-'mets, and all groſs bodies, perform their mo-'tions more freely and with leſs reſiſtance in 'this ætherial medium *than in any fluid, which* '*fills all ſpace adequately, without leaving any* '*pores, and by conſequence is much denſer than* '*Quickſilver or Gold* †? And may not its re-'ſiſtance be ſo ſmall as to be inconſiderable? 'For inſtance; If this æther (for ſo I will call 'it) ſhould be ſuppos'd 700000 times more 'elaſtic than our air, and above 700000 times 'more rare, its reſiſtance would be above '600000000 times leſs than that of water; 'and ſo ſmall a reſiſtance would ſcarce make 'any ſenſible alteration in the motions of the 'Planets in ten thouſand years. If any one 'would aſk how a medium can be ſo rare, let 'him tell me how the air in the upper parts 'of the atmoſphere can be above an hundred 'thouſand thouſand times' (i. e. an hundred millions of times) 'rarer than gold? Let him 'alſo tell me how an electric body can by 'friction emit an exhalation ſo rare and ſubtile,

† An Alluſion to the Fluid of *Des Cartes*.

and

'and yet ſo potent, as by its emiſſion to cauſe 'no ſenſible diminution of the weight of the 'electric body, and to be expanded through a 'ſphere, whoſe diameter is above two feet, 'and yet to be able to agitate and carry up 'leaf copper or leaf gold, at the diſtance of 'above a foot from the electric body? And 'how the effluvia of a magnet can be ſo rare 'and ſubtile, as to paſs through a plate of glaſs 'without any reſiſtance or diminution of their 'force, and yet ſo potent, as to turn a magne-'tic needle beyond the glaſs?'——— And may not I add? Let him tell him how the electrical effluvia can be ſo rare and ſubtile, as to paſs freely through a glaſs receiver, and yet ſo potent, as to act on a downy feather, with no leſs force and activity, than what we perceive to be acquired by the magnetic needle, from the beſt of loadſtones?—— The experiment may be made thus.

148. Let a downy feather be faſten'd to the top of a ſmall wire or ſtick, on a foot or ſtand, and cover'd with a tall glaſs receiver; then if a glaſs tube be rubbed within a foot of the receiver, the feather (notwithſtanding the interpoſition of the glaſs) will follow the motion of the hand rubbing the tube.

149. In all human probability no expedient could have been thought of, nor any experiment invented to have proved the exceeding rarity and elaſticity of æther, beſides thoſe principles on which that ſagacious enquirer ſo happi-

ly proceeded: Poſſibly they might for ever have remain'd in oblivion. For altho' the general Phænomena ariſing from the natural effects have been obſerv'd by many; yet we do not hear of any who ever repreſented it as poſſeſs'd of thoſe properties in ſuch an eminent degree, or that ever thought of any expedient whereby to compare it with the common air, and compute the proportion of the difference between thoſe properties in æther and the ſame properties in air.

150. From the effects then which Sir *Iſaac* had been mentioning, his concluſions were (as before obſerv'd) that æther muſt neceſſarily be at leaſt 700000 times more rare than the common air, and yet 700000 times more elaſtic. Properties, which altho' they ſeem incompatible with each other, are yet verified by the electrical fluid, in which thoſe properties are obſerv'd to exiſt in a very ſurpriſing degree, although the preciſeneſs of the proportion may not be eaſily determin'd: Probably, as before obſerved, there is no other means of making any tolerable computation than thoſe which are there laid down.

151. If thoſe natural properties ſo obvious in the electrical fluid are heedleſly paſs'd over and diſregarded, the experiments ſeem irreconcileable with each other, and conſequently inexplicable; but when thoſe properties are duly examin'd and conſider'd, they become ſuch a key as to render the moſt abſtruſe of them plain

and

and intelligible.

152. It muſt be confeſs'd that for a medium to be ſo much rarer than the air, and at the ſame time as much more elaſtic, appears like the greateſt paradox, eſpecially when we conſider the method of rarifying the air with the Pneumatic Engine, which is, to exhauſt the receiver of the main body of the air; for then, tho' the remaining part muſt be own'd to be much rarified, yet the elaſticity muſt, for that reaſon, be weaken'd in the ſame proportion.

At firſt ſight therefore I ſay, and before it is duly conſider'd, ſuch properties in the ſame medium may ſeem almoſt impoſſible; yet we ſhall find by the following experiment, that both may be much heighten'd, even in common air, by means of heat.—Let a blown bladder, for inſtance, when well dried, be untied and preſs'd with the hand till the air ſeems all excluded; then if the neck of it be tied again, and the bladder put into a very warm place, the remaining part of the air, which is conceal'd between the folds of it, will be ſo extended, that the bladder will very ſoon be as tight and turgid as if new blown: Here therefore is an increaſe of the elaſticity as well as of the rarity; the former is evident by the expanſion of the bladder, and the latter by its occupying more ſpace.———The ſame experiment will ſucceed, if inſtead of heating the bladder, it be put under the receiver of an air-pump and the air exhauſted, for then the in-

ternal air, conceal'd in the folds, will expand till it fills it, as before.

N. B. If it be objected that the foremention'd reasoning of Sir *Isaac* being deliver'd only as Queries, no great stress ought therefore to be laid on it: It may be answer'd, that the making of the experiment ‡, and the reasoning deduc'd from it; clearly prove it was then his opinion, that such a subtile medium not only existed, but also that it was universal. His 2d. Advertisement also at the beginning of his Optics shews that the principal reason for his putting them as Quæries was the want of experiments to prove them, and he expresses not the least doubt or hesitation concerning the truth of the doctrine he had been discussing. However had he made any doubt, the modern experiments have so verified the truth of his conjectures (if they were no more) as to put it past all future dispute.

‡ Optics. Quære 18.

CHAP.

CHAP. VI. PART I.

SECTION 153.

Lord Verulam's *Conjectures concerning a* ſubtile Fluid, *with the* Author's *new Account of a* more rare *and* active Part of Æther, *to which he gives the Name of* PNEUMA, or SPIRIT of ÆTHER.

THAT worthily eſteem'd and renown'd Philoſopher Lord *Bacon*, as well as Sir Iſaac *Newton*, was of opinion that a fluid, extremely ſubtile and active, exiſted in the pores of groſs bodies.

154. 'The Spirits and Pneumaticals' (he ſays) 'that are in all tangible bodies are ſcarce 'known.' And then inſtances in a variety of circumſtances wherein the world had been groſſly miſtaken about them*: Which obſervations, tho' now they appear ſtrictly juſt, yet could at that time be conſider'd, but as merely conjectural, having no ſufficient evidence to ſupport them, no proper experiments being

* Section, 70. 71, &c.

produced to countenance ſuch an opinion; it was therefore rejected: Nor was it capable of ſufficient proof before the ſurpriſing accidental diſcovery made by profeſſor *Muſchenbroek*.—— But ſince that, and other ſubſequent ones, we are furniſh'd with evidences which ſufficiently prove, that thoſe aſſertions were not mere *conjectures*, but rather like *predictions*, which are now clearly verified and realized by the plaineſt facts.

155. 'Thoſe inviſible things,' that noble Lord tells us, 'were but little enquir'd into; 'altho' they were the things, which GOVERN 'NATURE principally:' Thoſe ſpirits or pneumaticals were ſcarce known: Yet without the help of theſe, he aſſures us we can make no true analyſis and indications (as he expreſſes himſelf) of the proceedings of nature.—— This, we are now convinc'd, proves literally true; not only that ſuch ſpirits, or pneumaticals merely exiſt, but we have the higheſt evidence, even that of our ſenſes, pointing out to us that very identical agent it ſelf, in a more conſpicuous manner, and rendering it much more familiar and plain than ever we were able to do even the common air.

156. No doubt but that noble author and Sir Iſaac *Newton* meant one and the ſame agent or medium, tho' the former varies a little from the latter in his term, and makes uſe of the plural number || whereas Sir *Iſaac* always ſpeaks

|| Pneumaticals.

in

in the ſingular §.

157. But it is to be obſerv'd, that in the courſe of our experiments we frequently diſcover a much more rare, ſubtile, active part of æther, which has not yet been conſider'd, tho' its effects are obvious, and the neglect of attending to them has been the occaſion of various ambiguities. This ſuperior part of it, (for ſo I muſt call it) tho' it ſeems inſeparable from the ſubtile medium, diſcoverable by electrical experiments, is yet remarkably evident in many other Phænomena of nature. For this more active part therefore, I am at a loſs for an adequate Term: Should I call it ESSENCE OF ÆTHER, ſome would perhaps aſk what I mean by ſuch an eſſence, or elſe call it an unmeaning Term. I ſhall therefore, for diſtinction's ſake, take the hint from that great Author's *Pneumaticals*, and call it in brief, by its more original appellation, PNEUMA, or elſe, *Spirit* of Æther; and ſhall crave the liberty of the promiſcuous uſe of thoſe Terms: For I find I ſhall be conſtrain'd either to make uſe of them, or others ſimilar to them; ſince, as I ſhall ſhew, ſome other agent exiſts much more ſubtile and active than even the electrical medium itſelf. As no ſatisfactory method appears to ſolve the Phænomena of Nature without ſuch a Pneuma or Spirit, I ſhall in the firſt place produce my evidence to prove its exiſtence; and though

§ Spirit, Subtile Medium, or Æther.

we

we have very clear glimpses of it from the effects of many electrical experiments; yet in none more than one, which may be esteem'd purely physical.

158. Few wou'd imagine that such a subtile active Agent or Spirit is incessantly passing or escaping as it were from the upper regions (thro' every vertical bar of iron or steel) to the earth, and as we shall soon find, thro' every compass needle from the south to the north end, and to all rarified limits, and particularly to accumulations of the electrical fluid surrounding the rubb'd tube or globe.

159. The existence of such a Pneuma, or more subtile part of æther, is prov'd by the following easy experiment: If the lower end of a vertical rod of iron approach but the north-end of a magnetic needle, that north-end flies from it, and if the bar follows it, it will drive the needle round and round the compass. If it stop, the south-end of the needle will tend to the lower-end of the Bar: Instantly drop down the hand and the upper end of the Bar will drive the *south-end* round, and if the Bar stops, the north-end of the Needle is *driven* to it.

160. From these effects when duly consider'd, it also evidently appears, that the elastic Pneuma is constantly passing thro' the pois'd magnetic needle from the south thro' the north end:——If the Bar be inverted, yet still the upper and lower end of it produce the same effects, for which ever is made the lower end, it

it will ſtill be the north end, and the upper-moſt the ſouth.

161. That ſuch a ſubtile Pneuma is conſtantly deſcending from the upper regions, and which effects are render'd ſenſible by means of iron Bars, is evidently confirm'd by all ſuch as have been any time in a vertical poſition as Tongs, Poker, *&c.* But eſpecially by ſuch as have remain'd a long time in ſuch an erect poſition as the Bars of old Church-windows *&c.*

162. Are not theſe effects from the length of time the ſame Pneuma, or moſt ſubtile active part, that has been paſſing ſwiftly and violently thro' them in the ſame channels, and which has worn them away as it were, and in a very particular manner; for the upper and lower ends of thoſe ancient Bars when brought to the magnetic Needle act not only with much more vigour than a common Bar, but if they are inverted, the forementión'd Pneuma, tho' ſo rare and elaſtic, ſeems incapable of deſcending thro' them in the ſame channels, as it did thro' the *common Bar* when inverted, either end of *that* when uppermoſt or lowermoſt produces the ſame effects, but no longer than it remains uppermoſt or lowermoſt; whereas the old Window-bars act as natural magnets, and in the ſame manner as ſo many Loadſtones, each end of which, when inverted, acts in the very ſame manner as before, that is, the original lower end of the old Bar will ſtill drive the north-end of the Needle, notwithſtanding it is inverted and

made

made the upper end; and the original upper-end of it will repel the fouth-end of the Needle.

163. I fhall now fhew the effects of this Pneuma in electrical experiments.

N. B. This moft fubtile active part of the ætherial fluid cannot be the fame part which we obtain in our electrical experiments for two reafons, *firft*, becaufe in common experiments it pervades all metals indifferently, and in the fame manner; whereas, in the foregoing experiments the effects are render'd fenfible by means of iron Bars only; and *fecondly*, becaufe in electrical experiments it frequently appears from its effects, to act in a different manner from the *electrical fluid* as will be evident from the following, which if carefully attended to, many of the otherwife infuperable difficulties will difappear.

164. The electrical medium refufes as it were to come in contact with a glafs Body, infomuch that tho' the Leyden experiment fucceed ever fo well, a bit of Glafs introduc'd into any part of the circuit prevents the operation; whereas, if, as at *Sect.* 148. a downy feather be fix'd on the top of a vertical wire and cover'd with a glafs receiver, and if then a glafs tube be rubb'd at a foot diftance from it, the feather will follow the hand that rubs the tube as freely and as vigoroufly as if nothing were between. Is not this a much more fubtile fpirit than the electrical medium, fince that

per-

pervades not a glaſs while replete with air? The ſame Phænomenon is exhibited in a variety of other experiments, where we find light bodies are affected thro' the glaſs as freely as if nothing were in the way, and as vigorouſly as the magnetic needle, or ſteel-filings are mov'd beyond the glaſs at the approach of a magnet. If then according to Sir *Iſaac*'s 2d rule, '*To the ſame effects we muſt as far as poſſible aſſign the ſame cauſe,*' the magnetic virtue which moves the iron or ſteel filings beyond the glaſs, and the Pneuma or electrical virtue juſt diſcovered, which moves the Feather, Leaf-gold, Leaf-braſs, *&c.* ſo vigorouſly beyond the glaſs, muſt be the ſame identical ſubtile agent, acting in different capacities and in different forms. This Rule therefore, I beg may be particularly attended to, ſince many phyſical experiments will be greatly illuminated by conſidering it attentively, which would otherwiſe ſeem much more abſtruſe and unintelligible.

To render this more plain.

Let A B, Plate 2. Fig. 8. repreſent the glaſs Tube; F the Hand that rubs it; C D the glaſs Receiver; E the downy Feather. The ſpeck'd Lines and Arrows repreſent the *Pneuma* ſetting in from all the circumambient parts to the moſt rarified part, i. e. to the part of the glaſs Tube under the rubbing hand.

N. B. The glaſs of the Receiver being no impediment to the paſſage of the *Pneuma*, thoſe

M rays

rays of it, which happen to paſs thro' the Feather, cauſe the downy part to ſtretch forth its fibres in the ſame direction, viz. to the moſt rare limits, and which, for the above mention'd reaſon, follows the rubbing hand.

So intricate and perplexing are the ſurpriſing effects produced by the electrical experiments, when the ſolution is attempted by means of attraction, as to appear like the greateſt Paradoxes; and this, I am throughly ſatisfied, is the only reaſon why the ſubject has, after ſo many fruitleſs attempts to explain it, been given up as abſolutely inexplicable on any rational principle whatever: But the Pneumatical Scheme accounts for the Phænomena, and points out the effects in ſo plain a manner, as to remove all thoſe difficulties which before ſeem'd inſuperable, and makes them appear like natural and neceſſary conſequences; and this muſt always be the caſe, according as we reaſon from wrong or right principles. e. g. If any one rub a glaſs Tube and hold it at a proper diſtance from a downy feather, leaf-gold, or any other light bodies, he will be convinced there is no neceſſity for reaſoning ſo irrationally and unphiloſophically as to ſuppoſe the glaſs Tube, when rubb'd, both to attract and repel. But however,

If any one can render the effects of electrical experiments more intelligible, and account for a greater variety of the Phænomena of nature without ſuch a Pneuma or Spirit, I ſhall be well pleas'd to give it up, ſince we find

Nature

Nature extremely frugal in her firſt Principles, and as extenſive in her Effects; conſequently ſince ſhe is never found to act in vain, and as Sir Iſaac *Newton* obſerves, *more is in vain when leſs will ſerve*; he muſt be allow'd to be the beſt naturaliſt who accounts for her operations the moſt clearly and with the feweſt requiſites; that is, he whoſe data are the moſt concise, will be thought to have purſued ſimple nature with the greateſt preciſion, and in the moſt rational manner.——And here I muſt own, what I before hinted, that I ſhould not have riſqued the Cenſure of my Reader by adding the Term *Pneuma* to the philoſophical Vocabulary, had I not been under an abſolute neceſſity of doing it. ——The effects of ſuch a Pneuma or Spirit of Æther are in a variety of circumſtances too obvious to be denied by the careful enquirer, not only when he is employed at the electrical Wheel, as I obſerved, but when he conſiders many natural appearances, i. e. phyſical experiments ſtrictly ſo call'd: A more convincing inſtance we need not deſire than thoſe of the vertical iron Bars, the effects of which have ſo remarkable an affinity with thoſe of Loadſtones, and which they evidently acquire by the ſame means, viz. that of an inviſible elaſtic agent inceſſantly paſſing thro' them, and this like the magnetical agent affects no other metal or thing than Iron, which effects are ſo conſtant and ſo regular, that nothing 'tis imagined but invincible preju-

dice can prevail with them to deny the force of the evidence.——As to my own part I am clearly convinced of the general utility of such a Pneuma; many of the abstruse phænomena of nature will be greatly facilitated thereby, and render'd more intelligible; and mechanical agency will then be much farther extended on clear and rational principles, and consequently more firmly established.

'Tis presumed I may appeal to the ingenuous unprejudiced reader to determine which is most agreeable to right reason: Whether such an inconceivable attraction of which we can form no kind of idea; or whether such a natural agent which appears so plainly in a variety of different circumstances that we cannot easily mistake it.

For Instance, Which must appear the most probable, an *attraction* between the Sun and a Planet or the Sun and a Comet; or an *elastic agent* beyond the Comet to impel it back towards the most rarified part? especially if we consider that Comet in the year 1680, whose period is 575 Years, and which consequently takes up 287½ Years in passing to its utmost distance, which will not be till the Year 1967.

165. A variety of other satisfactory experiments might be produc'd to confirm the existence of such a Pneuma, in some of which it appears luminous, in others, by other effects: And first of some experiments in which it exhibits

hibits a *luminous* appearance: Those appearances of it, when *most active*, are seldom or ever known, but where the common air is either absent or else rarified in a very high degree.

166. As *first*, the flashing Lights that appear within side of a glass Tube or Globe when exhausted of their Air and rubb'd.

167. *Secondly.* When the glass receiver of an air-pump is exhausted, and a wire or rod of metal communicating with the vacuum is electris'd, there appears most remarkable flashes of light in the vacuum, if the air-pump be supported with an electric *per se*.

168. *Thirdly.* The ingenious Mr. *Martin's* experiment made with his long curvated tube mention'd in the 1st Vol. of his young Gentleman and Lady's Philosophy, p. 321. where the luminous appearance was like one continued stream, up one part of the vacuum and down the other, like an apparent rivulet of fire.

169. *Fourthly.* An experiment of Mr. *Haukshee*, 2d Edition, p. 85. he contriv'd two hollow glasses in such a manner that one of them might be exhausted and then put within the other; in this form he cou'd make them turn on their axes, in his machine, either the same or contrary ways, while his hand was rubbing the outermost glass. What was most remarkable, after the attrition of the hand ceas'd, and the motion of the glasses too, if he then brought but his hand near the outermost glass, a Pneuma or Spirit of Æther escap-

escaped from the hand, but was invisible till it had pass'd through both glasses, viz. till it came to the inside of the exhausted glass, where it appeared like a flash of lightning.

That it escap'd out of his hand cannot be doubted, since it did not appear but at the approach of his hand.

170. The following experiment is another of Mr. *Hauksbee's*, illustrating the above doctrine: I shall therefore give his description of it in his own words, with his sentiments thereon in the ensuing chapter.

CHAP. VII. PART I.

SECTION 171.

Mr. Hauksbee's *Experiments continued; with others tending to point out the same Agent, by means of its excessive rapid Motion towards the part most rarified.*

'I Have discover'd' says Mr. *Hauksbee* 'some properties of this electrical 'matter, which may seem wonderful 'to those who nicely consider them; 'since they afford us a sort of *representation of* '*the great Phænomena of the universe.* For, 'having observ'd that light bodies, placed near 'any part of the rubbed cylinder, seemed to 'be

'be equally attracted, I contriv'd a ſemicircle 'of wire, which I cou'd faſten at a conſtant 'diſtance, making it encompaſs the upper 'ſemicylindrical ſurface of the glaſs at 4 or 5 'inches diſtance: This wire had ſeveral pieces 'of woollen thread faſten'd to it, ſo as to hang 'down from it at pretty nearly equal diſtances: 'The length of them was ſuch, that being 'extended in a direction towards the center 'of that imaginary circle on the ſurface of the 'glaſs, in the plane of which the wire was 'placed, they wou'd then reach within leſs 'than an inch of the circumference of that 'circle; but if left to their own liberty, they 'hung in a parallel poſition to each other. 'The cylinder was placed with its axis paral-'lel to the horizon, and in this poſture it was 'turn'd ſwiftly about; and then by the rapid 'motion and agitation of the ſurrounding air, 'the threads were lifted up and bent upwards 'from the axis of the cylinder.

'All this while, here was only the ſwift mo-'tion of the cylinder round its axis without 'any attrition. But now, when I came to ap-'ply my hand to the lower part of this glaſs '(ſo ſwiftly whirl'd about) and conſequently 'to add *attrition* to the former motion, *the 'threads preſently began to change their directi-'on, and all harmoniouſly pointed to the center 'of the circle**, *in whoſe plane the wire was*

* Rather to the Place of Attrition.

pla-

'*placed*: Neither were they at all diforder'd
' or flung out of that pofition, by the wind
' occafion'd by that violent motion; but (as
' if there had been no fuch hurry of the air
' about them) they ftill perfifted in their cen-
' tral direction. And to render it moft fenfi-
' bly convincing, how abfolutely this effect
' depended upon the attrition, I found *I cou'd*
' *by fhifting the place of the attrition hither or*
' *thither, draw the threads towards this or that*
' *end of the cylinder*;' but yet they all ftill went
' uniformly converging towards fome *center* in
' the axis of it, fo that they form'd themfelves
' into a fort of conical furface.'

"Farther; if the wire with its loofe threads were *rever'd* fo as to encompafs the lower part of the cylinder, (as before it did the upper part;) yet the effect ftill anfwer'd with the fame exactnefs; *for the threads were all erected into fo many ftrait lines, ftill directing themfelves to a Center in the axis of the glafs.*"

172. "Hitherto the axis of the cylinder was placed *horizontally*: In the next place, I fet it in a *vertical* pofition, fo that it ftood perpendicular to the plane of the horizon, in which cafe, I made ufe of a wire hoop, which was neceffarily to be placed parallel to the horizon, fo that it might encompafs the cylinder in the fame manner as the femicircular wire did before: Only one part of the circular wire was left open, to make way for the touch of the hand which was to give the attrition. And the

wire

wire being thus placed it was evident that the threads (without ſome external force to ſupport them) muſt all flag, and hang perpendicularly downwards. Yet, as ſoon as the motion and attrition were given, the threads preſently began to be extended; and, as if they were become ſtiff and hard, form'd themſelves into an horizontal plane, their looſe ends pointing to a *center* in the axis of the glaſs, as before."

173. And thus in all ſorts of poſitions whatſoever, both of the wire, and of the glaſs too, were the threads acted by a ſort of centripetal *force*, to the laws of which they were always comformable. *Haukeſbee*'s Exper. p. 67. to 70.

174. Again. 'I took an *Hemiſpherical* ' glaſs of about ſix inches diameter: Into this ' I conveyed a *ſtick*, in manner of an *axis*, ' which had the woollen threads (formerly ' made uſe of) tied about it. The glaſs was ' ſcrew'd by the *neck* to one ſide of the *ſpindle*; ' and being fix'd on the *machine*, the great ' *wheel* was turned, and the friction made on ' the outward ſurface of the glaſs, as uſual. ' And now the threads preſented a Phænomenon, not a little pleaſant and ſurpriſing to ' behold; but yet ſuch as I expected and hoped for, in the contrivance of this particular ' *Apparatus*. For here was juſt the *reverſe* ' of what happen'd when the ſemicircular ' wire was placed on the outſide: That is, the ' threads *here*, iſſued like rays *from* a *center*

'*outwards*; as *there*, they *converged* to a *center* 'within†.' Mr. *Haukesbee*'s Exper. p. 76.

175. I shall now endeavour to solve the Phænomena from the visible effects.——The limits surrounding Mr. *Haukesbee*'s revolving glass were rarified by the attrition of the hand on the surface: That is, the air surrounding the glass was buoy'd up and borne away from it by the vastness of the elasticity of the accumulating Æther: The Air being thus displaced from the included limits; those limits may then be esteem'd similar to an exhausted glass Receiver, and they do in reality appear so from the effects; for the Pneuma then rushing violently into those rare limits to restore the equilibrium ‡, impels or drives those loose ends of the woollen Threads towards the most rarified part; i. e. to whatever part of the Cylinder the

† Since in both Cases the extremities of the Threads pointed to the *surface* of the Glass, viz. where the Friction was made; is it not more reasonable to suppose, that those extremities of the Threads were affected by that rubb'd Surface, rather than its *Center*, where there was no attrition?

‡ It cannot be the Air, which drives a feather or other light body into those rare limits surrounding the rubbed glass, the Air being first driven away from it by the accumulating elastic fluid surrounding it; consequently the effects proceeded from the same subtile Pneuma rushing into the artificial vacuum with that rapidity which caused the Threads to appear strait and stiff.

N rub-

rubbing hand was ſhifted.——Experiments to illuſtrate the preceding Arguments are the following:

176. If a glaſs tube be well dried, and then rubbed with the hand, it acquires an Atmoſphere (as we ſay) of the rare elaſtic fluid from the hand that rubs it: And if a piece of Thiſtle-down be releaſed from the fingers at a conſiderable diſtance, it will immediately begin to move toward the rare limits encompaſſing the tube: The Motion will be but ſlow at firſt ſetting out, but will be gradually accelerated till it arrives at the tube, probably in a reciprocal proportion of the ſquares of the ſeveral diſtances: For the motion appears much like that of a feather toward a fire, when releaſed at a proper diſtance from the chimney.——The Thiſtle-down is no ſooner at the tube, but it inſtantly acquires a capſula or atmoſphere of the elaſtic fluid, and is immediately repell'd out of thoſe rare limits again with great violence; and if the fingers that firſt releaſed it be near, it flies to them; and the atmoſphere of the ſubtile fluid encompaſſing the Down eſcapes to them, and the Down is as inſtantly driven back by the Pneuma into thoſe rare limits, as at firſt, where it again acquires an atmoſphere, and is as inſtantly driven out as before; and thus it will continue to do for many times without any freſh attrition at the tube, and if neither the hand, nor any other non-electric be near, it will be blown as it were quite away; and if

the tube follow it, the elaſtic fluid encompaſſing it, will, with the feather, be driven all over the room, or from near the bottom to the top of it, provided a ſmart ſtroke or two with the hand be now and then given to the tube: If the Down be purſued by the tube, ſuppoſe downward, and then removed and brought under the Down, it will firſt ſtop, and then move directly upwards. And to prove the propenſity of the little elaſtic Atmoſphere ſurrounding the Down to eſcape from the ſpring and preſſure of the common Air, when the Down is driven by the tube to a certain diſtance from the cieling, although the tube at the ſame time makes a full ſtop, yet the Down does not; for the ſame little atmoſphere having reached the cieling, the Down without any farther purſuit flies to it, where, the electric atmoſphere eſcaping, it is immediately impell'd by the Pneuma, and driven again to the Tube.

177. To illuſtrate the foregoing reaſoning, and to render thoſe two properties of extreme rarity and extreme elaſticity in the electrical fluid ſtill more conſpicuous; and to ſhew its exceeding great propenſity to eſcape from a condenſed ſtate to the earth.——If the experiment be varied in the following manner, the down or feather will be ſurpriſingly agitated: This, by way of diſtinction, I ſhall call my vibrating experiment.

178. Inſtead of the forementioned experiment with the tube, Let the Down be brought

near

near to a body electrifed at the Machine, as the prime Conductor, or which is better, a metallic Sphere, whofe furface is either polifhed or gilded: Such a body being electrifed is encompaffed with an Atmofphere of the rare elaftic Fluid, in the fame manner as the revolving glafs Globe, or as the foremention'd Tube; confequently the effects will appear the fame at the rare furrounding Limits.

179. Let the Down be brought within a few Inches of the electrifed body, which when releafed, the fame Phænomena will appear as before, but in much greater Perfection than when the Experiment was perform'd with the rubb'd Tube: Thofe alternate Pulfions and Repulfions will be performed with much greater agility and freedom, and the celerity of the Down will be increafed, as the diftance of the finger and electrifed body is leffen'd. When the diftance is about two or three Inches, more or lefs, (which due diftance is foon found by trials) the motion becomes fo exceedingly rapid, between the electrifed body and the finger which releafed it, that even the fight of the Down is loft, and the appearance of the motion too, which by being much too nimble for the eye, all that remains vifible is the colour of the Down only; confequently no tolerable computation of the number of vibrations can be made, which may perhaps be feveral thoufands in the fpace of a minute.

180. *N. B.* The lefs the fize of the Down

is,

is, the quicker are the vibrations, provided the diſtance of the electriſed ſphere and finger be proportionable, particularly if the downy parts at the extremity of the feather be clipp'd off, for otherwiſe thoſe more downy parts frequently adhere to the electriſed body, and the motion is thereby retarded.

181. OBJECTION. Since it is allow'd that *where Attraction ends, a repelling force begins*; 'tis preſumed to be more natural as well as more philoſophical to account for the Effects of thoſe Experiments, by virtue of theſe *two Properties*.

182. ANSWER. Not to inſiſt upon *that* common Poſtulatum which ſeems quite arbitrary, having never been ſufficiently proved; had the tube been really poſſeſſed of ſuch a remarkable attractive Power or Quality, as to draw the Down from the fingers at ſo great a diſtance, as in the former Experiment, how came it to loſe that Power ſo ſuddenly? or rather, how came ſo remarkable an Attraction to be immediately changed into an Impulſe? Had there been any attracting quality communicated to the Tube by rubbing it, how comes it to paſs that when the Down is deſcending towards the floor, (if the tube be then rubb'd and brought under it,) it will inſtantly move upwards to avoid the tube? Were not the Tube after rubbing it, poſſeſſed with a Power oppoſite to Attraction, and which acted on the Down with a much greater force than that of Gravity,

how

how came the Down, which was defcending, firft to ftop, and then to mount upwards?

183. To fay the truth, thofe two remarkable Properties, Rarity and Elafticity, appear fo predominant, that when Men make electrical Experiments, and reflect on the effects of them in good earneft, they naturally point out to us fomething diametrically oppofite to Attraction, even a Rarity generated in thofe parts which furround the rubb'd Tube, and into which as into a vacuum, the Pneuma fets in, and impels all light, unelectrifed bodies with a wonderful force and velocity thro' thofe rarified limits, as is confirmed by the following Inftance.

184. Mr. *Haukefbee*, altho' the firft Man who made any confiderable Improvements in Electricity, feem'd conftrained, contrary to his own Principles of Attraction, to fuppofe a current to impel, and drive light bodies to the Tube; for when relating the Effects of one of thofe Experiments with the rubb'd Tube, he tells us, 'The little bodies would be fometimes *drawn* '*to*, fometimes *thrown from* the Tube with 'violence; fometimes be fufpended for a fmall 'time in the Air, and at other times flip along 'the fide of the tube. They would repeat 'thefe leaps and boundings for feveral times 'together, and flutter up and down almoft like 'fo many Animals, rather than pieces of life-'lefs matter.' See p. 240. of his Experiments.

185. But when Experiments were made in vacuo, he obferved there was not then the fame

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tendency of light bodies towards the rubb'd Tube, though the Tube was replete with Air: He therefore concluded that the action of the common Air must necessarily contribute to the Phænomenon: He also observed, that if the Air was exhausted out of the glass Tube, and then rubb'd in the open air, it produced no such Effects among light bodies*.

186. Prop. 5. p. 244. '*As the internal Air* '*is necessary to the action of the Effluvia, so is* '*the external too: Because, though the Tube* '*was very full of Air, yet if rubb'd in vacuo,* '*the attractive Power was quite lost.*'

187. Prop. 6. '*As therefore the internal Air* '*seems necessary, either to assist the electric Mat-* '*ter in its Motion outwards, or at least to pre-* '*vent its retiring inwards; so the external Air* '*appears to be as necessary to carry the light bo-* '*dies* (which we say are attracted †) *towards* '*the Tube.*

188. 'For if by the heat and rarefaction 'consequent upon the attrition, *the Medium* '*contiguous to the Tube*, be made *specifically* '*lighter*; then of course, *to keep up the balance,* '*the remoter Air*, which is *denser*, must press 'in towards the Tube, and so carry away (in 'the Torrent) the little bodies lying in its

* The Effects were then within side of the Tube.

† Notwithstanding Mr. *Haukesbee* confesses the Phænomenon appears to be performed by Pulsion, yet we see, he cannot forbear calling it Attraction.

'way

'way thither alſo.' Thus Mr. *Haukeſbee* ſeems naturally conducted to the ſame concluſion, or nearly, as if he had had then in view the ſame Rarity and Elaſticity of the electrical Fluid, which we have ſince found in it.

189. ☞ Thus we ſee when preſs'd with the difficulties attending electric Attraction, how natural it is to have recourſe to an oppoſite Principle, viz. that of Impulſe.

190. From all which it muſt ſeem reaſonable, as well as agreeable with Experiment, to ſuppoſe that the limits ſurrounding the electriſed gilded Globe ||, the rubb'd Tube, &c. appear from the Effects to be ſo extremely rare, as that light Bodies near thoſe limits are impell'd as forcibly into them by the newly diſcover'd *Pneuma* or Spirit of Æther, as into a Torricellian Vacuum were it poſſible to form one in the open Air, where it inſtantly acquiring a Capſula or Caſe of the rare elaſtic matter is as inſtantly repell'd out again. On this reaſonable Poſtulatum therefore (if it may not rather be term'd an Axiom) depends the principal Part of the whole electrical Phænomenon, and by it the moſt abſtruſe Parts (which otherwiſe appear ſo much like inexplicable Paradoxes in thoſe ſuppoſed alternate *Attractions* and *Repulſions*,) will be render'd intelligible, and the Experiments no longer ſeem irreconcileable with each other, as has been repreſented, but rather as the natural agreement and neceſſary effects of their proper Cauſes.

|| See *Sect*. 178.

CHAP. VIII. PART I.

SECTION 191.

Of the SOURCE *from whence this* Subtile Matter *is obtain'd in the Experiments.*

ACCORDING to my 2d. fundamental Principle, its Exiſtence is *uniſal* i. e. *in all Space; not only in all open Spaces, but in all minute ones, even in the ſmalleſt Vacuities or Pores of the moſt ſolid and compacted Bodies:* And notwithſtanding it long eluded every Senſe; yet it doth really exiſt and is actually preſent in every thing we either handle or ſee: And the Reaſon it eſcaped our Senſes ſo long was from its very Nature, that is, it was not only inviſible but ſo ſubtile and volatile as always to evade a ſtrict Scrutiny: For otherwiſe Sir *Iſaac*, who ſought moſt diligently after it, muſt have diſcover'd it more minutely.

192. If then every groſs Body is replete with it, the largeſt Bodies muſt contain the greateſt quantity, and conſequently the Body of the Earth the moſt of all, which ſeems to be the Fountain from whence it is obtain'd and to which it perpetually tends; and this will evidently appear to be the Caſe from the following Experiments.

193. Mr. *Haukesbee* was of opinion, that the electric matter was emitted from the internal ſubſtance of the Glaſs on which the Attrition was made. See his Phyſico-mechan. Exp.

194. This was alſo the opinion of many others after him; and ſoon after the preſent Improvements commenced, many ſuppoſed it to be obtained from the Air; but on examination it appeared otherwiſe: For moſt Experiments made by way of Trial on that ſuppoſition, when but a little varied, were found to claſh with, and contradict each other.

195. On farther examination it plainly appear'd from a train of Experiments to be emitted from the pores of the Inſtrument of Friction at the rubb'd glaſs, and ſupplied from the Earth thro' contiguous Bodies; and then the Experiments, as ſo many clear evidences, were always conſiſtent with each other, tho' ever ſo much varied; and tho' chang'd into many different forms or ſhapes, no contradiction or claſhing then happen'd.——Experiments which prove it are ſuch as follow:

196. *Firſt*. If the Fire be emitted from the pores of the Inſtrument of Friction and ſupplied from the Earth; then, conſequently, if a Perſon's Hand be the Inſtrument, the fire muſt be flowing through his Body all the time, *viz*. from his feet to the palm of his hand. This is verified to ſenſe, if the Room be darken'd; for between ſuch parts of the palm as are nearly in contact with the revolving glaſs Globe, it

appears like exceeding fine threads of fire iſſuing from numberleſs pores. Are not theſe ſupplied by the contiguous particles, and thoſe by the next, quite thro' the Body? But to prove that it enters at the ſame time into his feet from the floor, let him ſtep on a cake of Reſin*, which will intercept the communication with the floor, and after that if he put but his Toe very lightly to the floor, the fire appears plainly between them, eſpecially if the ſhoe be off; And ſtill more plainly, if a finger of a Perſon on the floor be brought to the foot, for then it will be not only viſible but may be plainly felt and heard to ſnap or explode.

197. *Secondly.* If the Perſon rubbing the Glaſs only ſtands on folded woollen, inſtead of reſin, it is ſufficient; for then likewiſe it may be

* The method commonly made uſe of to prove the electrical Fluid to be deriv'd from the Earth, was by mounting the whole Machine on original Electrics. But all that formality may be ſpared, for if the Inſtrument of Friction only be thus ſupported, it is ſufficient. This may be done by taking off the Cuſhion that rubs the glaſs Globe, and if inſtead thereof, a Perſon ſteps on a Cake of Reſin, or a glaſs Stand, and applies the palm of his Hand to the revolving Globe, the leaſt reflection will be ſufficient to inform us, that the ſame end muſt be anſwer'd in every reſpect, ſince the middle Zone of the Globe, from whence all the other parts of the Apparatus are ſupplied, can be no way ſupplied it ſelf but from the Inſtrument of friction.

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ſeen and felt, if a finger be brought near to the foot, or to any other part of the Perſon ſtanding on the woollen. —— *N. B.* The folded woollen muſt be of ſome conſiderable thickneſs.

198. *Thirdly.* If a Perſon rubbing the glaſs Globe ſtand on a chain when folded together; the fire, in paſſing from the floor to the foot, appears between many of the links. And,

199. *Fourthly.* I have ſometimes obſerv'd it, when the weather has been favourable, to appear between the floor and the toe, tho' there was nothing under the other foot beſides the dry ſhoe.

200. From ſuch hints we are made ſenſible that the Experiment may be varied many different ways, each of which ſerves to ſtrengthen and confirm the Theory.

201. Since then the electric matter is ſo clearly prov'd to be obtain'd from the Earth thro' denſe bodies, it will be natural to expect it to ſhew as great a propenſity to return to it again, which accordingly happens.

EXPERIMENT. When a Perſon is electrifed on the Reſin-cake, if he put the toe of his ſhoe to the floor, the accumulation vaniſhes both from off himſelf and every part of the inſulated wires, be they ever ſo far extended, and it all darts inſtantaneouſly into the Earth. To prove this, let him lift up his foot, and the accumulation takes place again, and as inſtantly eſcapes at putting it to the floor; and this alternately, as often as the foot is removed

from

from one situation to the other. But that it is obtained from the Earth, and returns again to the Earth is now so well known, as to need no farther proof; for to say the truth, almost *all* Experiments prove it.

CHAP. IX. PART I.

SECTION 202.

On electrical *and* non-electrical *Bodies.*

I Have before cursorily remarked, that the World, many ages past, was not a Stranger to that Property in Amber of attracting many light Bodies after rubbing it; and also that 'tis natural to suppose that the term Electricity came from *Electron*, the Greek Name for Amber, which was doubtless the thing that *first* discover'd any signs of such an attractive Quality after Attrition, and was probably the Reason for calling that Property electrical, not only when it appear'd in Amber, but also whenever the same attracting Quality was discover'd in any other Body after rubbing, for then that Body was also said to be electrical: So far, all appears natural, and without any great Impropriety; but yet this was the cause of a very remarkable one, namely, that as Bodies having such an attractive quality

were

were called *electrical*, so it was imagined that those which were not endued with such an attractive quality after rubbing them were entirely devoid of that Principle, and were therefore term'd *non-electrical*: Whereas in truth the Effects of modern Experiments inform us, that there is no such thing in nature as a non-electric in such a strict sense, or, however, none that we are conversant with.

203. Dr. *Franklin* very judiciously observes, that 'the terms electric *per se*, and non-electric 'were first used to distinguish Bodies on a mistaken supposition, that those call'd electrics '*per se* alone contained electric matter in their 'substance, which was capable of being excited by Friction, and of being produced or 'drawn from them and communicated to those 'call'd non-electrics, supposed to be destitute 'of it: For the Glass, *&c.* being rubbed, discover'd signs of having it, by snapping to the 'finger, attracting, repelling, *&c.* and could 'communicate those signs to Metals and Waters.—Afterwards it was found, that rubbing 'Glass would not produce the electric matter, unless a communication was preserved 'between the Rubber and the Floor; and 'subsequent Experiments proved that the electric matter was really drawn from those Bodies that at first were thought to have none 'in them. Then it was doubted whether Glass 'and other Bodies call'd *electrics per se* had 'really any electric matter in them, since they

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'apparently afforded none but what they firft
'extracted from thofe which had been call'd
'non-electrics. But fome of my Experiments
'fhew that Glafs contains it in great quantity,
'and I now fufpect it to be pretty equally dif-
'fufed in all the matter of this terraqueous
'Globe. If fo, the terms electric *per fe*, and
'non-electric, fhould be laid afide as im-
'proper: And (the only difference being this,
'that fome Bodies will conduct electric mat-
'ter, and others will not) the terms, conduc-
'tors and non-conductors, may fupply their
'place.' See Mr. *Franklin*'s printed Letters on Electricity, p. 95. 2d. Edition.

204. *Before the late Difcovery*, almoft all Philofophers in general, who treated of Æther or a more fubtile Medium than the Air, were miftaken in one particular relating to it, namely this: They imagined that a Medium fo extremely elaftic and fubtile muft *freely* pervade all grofs Bodies whatever, that we are converfant with, but this proves contrary to fact; for tho' all grofs Bodies appear replete with fuch a fubtile elaftic Fluid, yet nothing can be much more evident from Experiment than that there is a great variety of Bodies in which it is fixed, and all thofe Bodies feem to refufe as it were a free entrance to the fubtile Fluid. Of this clafs are all the moft inflammable Bodies, unlefs common fpirituous Liquors may be excepted, fince, thofe may be electrified, and Sparks drawn from them, con-

trary

trary to what happens from moſt other inflammable bodies.——All unctuous bodies in general are of this kind.——Alſo Amber, Glaſs, and many other hard brittle ſubſtances. Likewiſe many rare bodies, as Silk, the Hair of Horſes, Cats, and probably of many other Animals; but 'tis found fixed in no compound body whatſoever ſo much as in the common Air, which is therefore the moſt remarkable of all thoſe termed Electrics.——In ſhort all Bodies are more or leſs of this kind in proportion as their component parts partake more or leſs of one or more of thoſe kinds of ſubſtances, whoſe nature is to fix it.

205. Bodies termed non-electrical are ſuch as may be electriſed; that is, ſuch bodies as when ſupported with electrics *per ſe*, the electrical fluid will accumulate and form a Capſula, or Atmoſphere on them, if any part of them be in contact with the prime conductor, or nearly ſo: But if thoſe ſupported non-electric bodies communicate with the Earth, either directly or indirectly, no ſuch Phænomenon is exhibited; for it appears from experiment to eſcape thro' ſuch bodies into the Earth.

206. The Bodies it pervades moſt freely are ſuch as follow:

207. *Firſt*. All Metals in general, and all common Liquids, particularly common Water.

208. *Secondly*. All animal Bodies, in proportion to the juices they contain; alſo Vegetables: So that when a vegetable is green and

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replete with juices the electrical fluid pervades it freely; but when it becomes more dry, and the pores consequently are enlarged, the grosser air insinuates, which is a sure impediment to the free passage of the Æther. And universally, as the composition of Bodies partakes more or less of either moist or metalline particles, so it pervades them more or less freely.

209. By divesting Bodies of moist particles, or by adding moisture to dry Bodies, they are render'd either electrics, or non-electrics. Vegetables, as before observ'd, when green and replete with juices are vigorous non-electrics, but as they grow more dry, and the pores consequently more enlarg'd, that property becomes proportionably more feeble, particularly in such as are of the most porous and hollow kind. A stick of light, loose wood, for instance, when moist, acts as a non-electric; but when well dried in a Baker's Oven, it is changed into a vigorous electric. —— I took the hint from the miscellaneous part of Mr *Martin*'s Gentleman and Ladies Philos. Vol. 3d. p. 579, where his Correspondent assured him that dry wood was an electric; and underneath was the following Distich:

210. *A Mopstick well bak'd and by Flannel excited,*
Became so electrical, Betty *was frighted.*

211. I tried the Experiment and found it, when rubb'd, to answer almost as well as a glass Tube when rubb'd. Light Bodies were put in motion by bringing it near them; and if the

Room

Room was darken'd, a luminous appearance was ſeen under the hand that rubb'd it, in the ſame manner as if it had been a glaſs Tube.

212. I was agreeably entertain'd with my Mopſtick, ſince I could at pleaſure render it either an electric or a non-electric, by baking or moiſtening it; but if it be ever ſo well dried, when laid *by* a day or two, that property gradually diminiſhes, and in a little time entirely diſappears, eſpecially if the Air be in a moiſt and damp ſtate.

213. Are not thoſe different Phænomena the Effects of different degrees of Purity of the Air contained in Bodies; i. e. from the pureſt Air contained in the denſeſt Metals, down to the groſſeſt common Air contained in a hollow Spunge? Were the pores of any Bodies ſo ex-extremely fine as to admit of the pure primary Air only, ſuch Bodies would be the moſt perfect non-electrics of all others. Whilſt the pores of Bodies remain ſo ſmall as to admit the more pure Air only, ſo long the ſame Air moves freely in them; but when the pores are enlarged, as in the dry ſtick or dry ſpunge, the groſſer Air can then inſinuate, and by means of the terreſtrial particles contained in that groſſer Air, it adheres firmly to the groſs Body in the manner before obſerv'd.

214. This appears from Experiment to be the true reaſon of the difference between electrical and non-electrical Bodies. But whether Conductors and Non-conductors are the moſt

adequate Terms that might be chosen, whereby to express the true quality of electrical and non-electrical Bodies, will best appear after the following Experiments are impartially considered.

215. Let A B, Plate II. fig. 3. be the glass Globe; C D the prime Conductor; and E F a Wire coated all over very thick with Sealing-wax *, supported in such a manner that the end e may come within a quarter or half an Inch of the end d of the prime Conductor. — When the Friction at the glass Globe is made by means of the hand or cushion, and the subtile fluid collected, it flows from thence all round the prime Conductor, where, as the quantity increases, the accumulation consequently extends to a greater distance from it, and by being much more elastic than the common Air, it extends its dimensions, buoys up and bears away the Air from the prime Conductor, as far as the speck'd line, c, d, h, g, which, suppose a foot distance from it, the most pure, rare, and elastic part is at the prime conductor it self, and from thence gradually decreases, so as from that to be less pure, less rare, and less elastic, till at length it terminates at the circumference c, d, h, g, and becomes equally gross with the common Air. And since the pure Air or electrical Fluid accumulated

* The electric Sealing-wax on the surface of the Wire prevents the Accumulation, that would otherwise prevail on it.

on

on the Conductor, and the common Air mutually repel each other, the former consequently remains in a very condensed state under the pressure and weight of the latter, and rests not only as an abuttment against the end e, of the coated wire, but by this means, the whole column of the electric Air contained in the internal part of the coated wire is condensed, and as Dr. *Franklin* expresses it, '*Each Particle* '*that was in it before, pushes its neighbour quite* '*to the farther end*,' and the reason or cause, which prevents it from flying out at the end f is the same which prevents its escaping from the condensed state when accumulated on the prime conductor, namely, the repellent spring and pressure of the ambient Atmosphere, as may be proved by a Person laying on a finger at that end of the coated wire; for at the same instant the whole accumulation on the prime conductor vanishes, and escapes through all the contiguous Bodies into the Earth, *viz.* thro' the Conductor, the coated Wire and the Person: All that remains perceptible is a constant stream of fire between the end d, of the prime Conductor, and the end e, of the coated Wire: This is proved by removing his finger, for then the fire between d and e disappears, and the accumulation again takes place on the prime Conductor.——If he bring his finger within a quarter or half an Inch of the end f, of the coated wire, a spark of fire will dart from it to his finger, and at the same instant

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an equal ſpark will appear between the Conductor and the other end of the coated Wire, i. e. between d and e.

216. To convey a ſtill clearer Idea of the manner it is performed to thoſe who are not converſant with electrical Experiments, I ſhall, by way of Illuſtration, attempt a ſimilar Experiment, but made with water.

217. Let A B C D, Plate II. fig. 4. be a Ciſtern or Reſervoir of water, and D G a Pipe near the bottom. —— It is manifeſt by the Figure, that if the Cock at E be open'd, and then cloſed again, whatever quantity of water was voided at G, an equal quantity (to preſerve an equilibrium) enter'd the ſame Inſtant at the other end D of the pipe, by which means the whole column of water, a e, in the pipe was protruded forward: So that in this caſe alſo Dr. *Franklin*'s Language is pertinent, *viz. each particle that was in it before puſhes its neighbour &c.* in a ſimilar manner to that part of the foregoing Experiment, when a ſpark was drawn off at the extremity, by means of the approaching finger. —— The former Experiment, has, however, the advantage of the latter, in that a ſupply is obvious to the ſenſe; for when a ſpark is drawn off from the end f, of the coated wire, an equal quantity is viſible at the other end e at the ſame Inſtant; whereas in the latter that viſibility is wanting*: But this however is very

* Were the Pipe of the Ciſtern, Glaſs, and filled with a tinged Liquid, the forementioned Effects would then be viſible, clear,

clear, *viz.* that the fire in the coated wire is ſupplied in a manner ſimilar to the water in the pipe.

218. If the finger be continued at a ſmall diſtance from the end f of the coated wire, in the former Experiment, the fire eſcapes to it and is continued in a conſtant ſtream, which paſſeth thro' the Perſon into the Earth, as thro' a proper vehicle, and a ſupply is viſible between the prime Conductor and the other end of the coated Wire, that is, between d and e, where a conſtant ſtream appears alſo: So that Metals act as Conductors of Electricity, in like manner as the Reſervoir and Pipe conduct the Water.

219. *N. B.* If any one can ſtill doubt, whether the Fire really paſſeth through the Perſon into the floor, the truth may be proved by his ſtanding on the Reſin-cake, where, when he is electriſed, not the leaſt ſpark appears, tho' his finger be brought ever ſo near the end of the coated Wire, the communication with the Earth being then intercepted by means of the Reſin-cake on which the Perſon is ſupported.

CHAP.

CHAP. X. PART I.

SECTION. 220.

Concerning the ſimilarity *of* electrical Fire, *and the* Fire *of* Lightning; *and of electriſing* plus *and* minus: *With Remarks on deſtroyed and reſtored Equilibriums.*

I Have before taken notice how greatly the World, and paricularly Electricians are indebted to the worthy and indefatigable Dr. *Franklin* for the many uſeful hints in that hitherto uncultivated branch of Philoſophy, *Electricity.*

221. How early did he diſcover the extenſive effects of the electrical Agent, and that the Fire diſcoverable in electrical Experiments was the ſame with that of Lightning, by inventing ſuch deciſive Experiments, which put it paſt all future diſpute; ſuch as his electrical Kite, at p. 106. of his Letters on Electricity; his pointed iron Rods at the tops of lofty Buildings, with other uſeful hints concerning what he calls poſitive and negative Electricity, and reſtoring of deſtroyed Equilibriums?

222. Were we but equally induſtrious to examine and pry into that abſtruſe Phænomenon

tion of Nature, we had probably long before this time made very confiderable advances and advantageous Improvements in that way: As

223. *Firft*. Since the Fire exhibited in electrical Experiments and that of Lightning prove to be one and the fame thing, we are no longer in any doubt, (as it feems we were) whether Fire be a permanent Principle or not, or whether we can generate and deftroy it at pleafure juft as we do Heat.

224. Surely the judicious Philofopher will never let prejudice in favour of former Opinions fo far prevail with him as to deny it to be Fire, merely becaufe it neither burns nor exhibits any Light; fince we find the largeft quantity of Fire breaks out, and with the greateft violence, from the darkeft Clouds. Would it not then favour much of prejudice to former Opinions, Terms, and Definitions, to hear any one infift that it is not Fire till the *Light* appears, and as foon as that is over, that the Fire is annihilated notwithftanding the Principle remains? Can any thing appear much more like invincible prejudice than to find ingenious Men, after racking their brains, roundly affert, that it is as improper to call the electrical matter (and confequently the matter of Lightning) by the name of *Fire*, as it would be to call *Air* by the name of *Sound*? and that a principal reafon for it was, becaufe it was not agreeable to the Chymifts Senfe of the word, tho' it was next to impoffible for the *Chymifts* themfelves to form

any juſt Idea of the nature of true Fire, before this fluid was diſcover'd. Was it very likely that *they* or any one elſe ſhould imagine that true Fire was ſo much in the form of Air, as we now find it to be?

225. *Secondly.* If the Fire of Lightning and that of Electricity be the ſame, it would be but natural to ſuppoſe that each was ſupplied from the ſame ſource, and that the means by which it prevails in both, ſhould have ſome remarkable affinity and agreement.

226. It appears by undeniable evidence, *Sect.* 194. 195. *&c.* that the great Fountain, from whence the electrical Fire is obtain'd, is the Body of the Earth.

227. And from the general Conſent of the moſt eminent Naturaliſts, the Fire of Lightning proceeds from the ſame ſource.

228. 'Sir Iſaac *Newton,* for example, is of 'opinion, that there are ſulphureous exhalations 'always aſcending into the Air, where they fer'ment with the nitrous acid, and ſometimes 'take fire.'—— Dr. *Franklin* endeavours to point out the manner it is effected, and why the Clouds are electriſed negatively. 'When a 'portion of Water,' he ſays, 'is in its common 'denſe ſtate, it can hold no more electrical 'fluid than it has; if any be added it ſpreads 'on the ſurface.'

229. 'When the ſame portion of Water is 'rarefied into vapour, and forms a Cloud, it is 'then capable of receiving and abſorbing a

'much

'much greater quantity, there is room for each 'particle to have an electric Atmoſphere.'

230. 'Thus Water, in its rarefied ſtate or in 'the form of a Cloud, will be in a negative 'ſtate of electricity; it will have leſs than its '*natural quantity*; that is, leſs than it is natu-'rally capable of attracting and abſorbing in 'that ſtate.' See Mr. *Franklin*'s Letters on *Electricity*. p. 119.

231. 'A Cloud being by any means ſuppli-'ed from the Earth, may ſtrike into other 'Clouds that have not been ſupplied, or not ſo 'much ſupplied; and thoſe to others, till an '*equilibrium* is produced among all the Clouds 'that are within ſtriking diſtance of each other.' ibid. p. 120.

232. Nor are we any longer at a loſs for the reaſon of that which before ſomewhat per-plex'd the ſubject, namely, by what means it is kindled up into fire, as we called it: Of this we are now very clearly informed from almoſt all Experiments. ——— We cannot bring ſo much as a Finger or iron Rod to the prime Conductor, when electriſed, without having an hint of the manner, how it is performed; but if it be collected in the glaſs Receiver, much more is accumulated and is much longer re-tain'd, although much more condenſed than on the prime Conductor, it being frequently re-tain'd there for many hours, ſometimes for a whole day. At ſome other times the accumu-lation is ſo great and riſes ſo high as to burſt

out ſpontaneouſly as it were.—— I once took the Phial being charged, and carried it through ſeveral Rooms, where it burſt in the hand of its own accord, i. e. without touching the Cork-wire *. It is well known to be always retain'd much longer in ſuch a Receiver, than *in* or *on* any other thing, and particularly if the inſide of it be furniſhed with Quickſilver.

233. When one of thoſe Receivers are charg'd ſo high as to burſt out of its own accord, the effects are then ſimilar in every reſpect to thoſe of what we call a Thunder-cloud and its effects, which, ſo long as the inviſible Fire remains accumulated on it, ſo long we perceive no effects; but when it becomes ſo highly charg'd with the accumulated fluid that the ſurrounding Air is no longer capable of retaining it, it then burſts out all at once and becomes viſible, and is then, it ſeems, what is allowed to be Fire.—— Probably ſuch univerſal Fire would be always viſible were it not for the great number of particles of groſs matter with which the Air is replete; for remove but

* Thoſe Experiments are like ſo many clear Proofs that true elementary Fire is inviſible when in its natural State, and that neither Heat nor Light are eſſential Properties of it. But the attrition it ſuffers when paſſing thro' the ſmalleſt portion of Air, renders it luminous, and in ſome degree hot; ſince it is then capable of kindling combuſtibles into a real *Flame*, and of burning Tinder.

the common Air, and the electric Fire instantly becomes visible: e. gr. If one end of a Wire communicate with the prime Conductor and the other end with the inside of an exhausted Receiver, supported on an electrical Body, the Wire is no sooner electrised, but flashes of light appear in the vacuum *, and if an exhausted glass be turn'd briskly on its Axis with a hand at the same time on its surface, the inside of the glass will be illuminated, which never happens when the glass is not exhausted. See Mr. *Haukesbee*'s Experiments, p. 45.

234. Many more of Mr. *Haukesbee*'s Experiments very clearly countenance such an opinion, particularly those relating to what he calls mercurial Phosphorus, which readily exhibits a light in vacuo, and is always extinguished by the admission of the common Air †.

235. So that in reality when the electrical Fire bursts out at the Machine, we have true Lightning and Thunder in miniature, and the greatness of the Report is always proportionable to the quantity of the Fire which then escapes from its condensed state; which Report is the effect of the restoration of the equilibrium that was destroyed at the breaking forth of the Fire, that is, the Fire at breaking with violence from the accumulation on the Cloud

* See *Section*, 167. † See Mr. *Haukesbee*'s Experiments from p. 6. to p. 29.

de-

deſtroys the equilibrium by forcing the Air aſunder, which inſtantly cloſing together again with equal violence is the cauſe of the Report. The effects are the ſame at the electrical Machine. To prove that the effects at the reſtoring of the equilibrium are equal, if not greater, than at the deſtroying of it, I ſhall relate an unhappy accident, which happen'd on the ſpot.

Auguſt 11th. 1762.

236. A London Carrier in the City of *Worceſter* having brought down 3 Barrels of Gunpowder, ſet them, whilſt other Articles were unloading, by the Ware-houſe Door, on one ſide of the Gate-way: The Caſks being not ſo cloſe and firm as they ought to have been, ſome of the powder was unluckily ſcatter'd, and a little Boy, ſeeing a Train of Gunpowder, thought to divert himſelf by ſetting fire to it, which kindled the whole, and blew up the Ware-houſe, Gate-houſe, and part of the Dwelling-houſe. The Houſes on the oppoſite ſide of the way ſuffer'd greatly, and others in proportion to their diſtance and ſituation, particularly the Windows and Tiling of ſome Buildings more remote.

237. The Windows of the Town-Hall, tho' at a very conſiderable diſtance, and behind the Houſe of the ſaid Carrier, received ſome damage from the ſhock, as alſo thoſe of the Pariſh Church of St. Swithin, which were at a ſtill greater diſtance. The Report was ſo great as to be heard 9 or 10 Miles, particularly by

ſome

ſome Reapers in a field adjoining to the Town of *Perſhore*. The Child, who was the unhappy Inſtrument of all this Miſchief, may be well ſuppoſed to have paid his Life for it, and was ſo terribly burnt and withal ſo black, that the only mark left whereby to diſtinguiſh him was his Buttons.

238. The Houſe of a very reſpectable Clergyman, near the place where this Cataſtrophe happen'd, ſuffer'd greatly from the ſhock.

239. But what was thought the moſt remarkable Circumſtance was, that the glaſs of the windows at the back of this houſe was forced *inward*, as well as that on the forepart, and with an amazing violence, inſomuch that by being confined by the bands to the middle upright bar, the whole pane or column of glaſs was wrapped as it were round the aforeſaid bar. And not only the glaſs was thus forced, but the window-frame alſo was bent inward.

240. A Summer-houſe in the garden at a conſiderable diſtance from the dwelling houſe, had a window ſhatter'd alſo by the ſhock, which window was likewiſe on that ſide of the houſe that was fartheſt off from the place of the exploſion, and was conſequently the effect of the return of the elaſtic Air at the reſtoring of the equilibrium.

241. From hence it appears that the force is nearly, if not altogether as great at the reſtoring of the equilibrium as at the deſtroying of it, i. e. that the expanſive force, occaſioned

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by the firing of the gunpowder, was not greater or capable of doing more execution than the return of the expansive Air, after being impell'd by the force of the Fire. *viz.* action and reaction appeared to be equal.

In a similar manner the effects are produced at the discharging of a piece of Fire-arms; the same when a Phial or Sash-pane is charg'd so high with electrical fire as to burst forth of its own accord, and even at the breaking out of the least spark from the electrical Apparatus. And can we make any doubt whether a flash of Lightning and clap of Thunder are effects of a similar cause, or whether the accumulation on the Thunder-cloud and the explosion of the Fire are Phænomena exactly similar to accumulations and explosions of Fire at the electrical Machine, each of them being an effect of a destroyed and restored Equilibrium?

CHAP.

CHAP. XI. PART I.

SECTION 242.

A Description of the Construction and Use of the Condensing Phial, *or* Glass Receiver.

HAVING more than once attempted to explain the Leyden Experiment, *viz.* the reason of that great Force of the electrical Æther, which we experience at the discharging of the Phial or Glass Receiver, namely, how that convulsive shock is generated and propagated through the non-electric Circuit, I had almost given it up as inexplicable; but the effects of such surprising force, at the restoring of the equilibrium of the Air, as above mentioned, have encouraged me to venture once more at the solution of that difficult Problem, since there appears no other method that affords any tolerable satisfaction; and I am fully convinced there is no other way of accounting for it. But I shall first shew the manner how the Phial is constructed.

243. This Phial being of the greatest Importance in making electrical Experiments, worthily merits a particular Description. Scarce any other way could have been invented or

thought of, capable of arresting and confining a quantity of the subtle Æther sufficient to make the Experiment.

244. If this had not been wonderfully revealed to us, (for I cannot help calling it a Revelation) we had still been ignorant of any great Strength, Power, or Force in electrical Fire.

245. The way and manner this great Secret was discover'd to M. de *Muschenbroek*, was, as before observ'd, from a seeming accident, i. e. by means of a Phial partly filled with Water; for which reason all were at first prepared in that manner: *viz.* A Phial, nearly filled with Water, was suspended to the Gun-barrel (i. e. the prime Conductor,) by a hooked wire leading through the Cork to the Water.

246. Mr. *Rackstrow*, in Fleet-street, kept this Fire in a Phial with Water for ten hours, and others a longer time; but Mr. *Monniers* kept it so for thirty six hours: And every Operator in Electricity very well knows that it may be kept in close connexion with Water for a very long time, particularly if the Water be made and kept warm.

247. The more dense the fluid contain'd in the Phial was, the more power there appear'd of holding it together; for, when it was furnished with Mercury instead of Water, so much was oftentimes detained as to occasion it to burst of its own accord.——— Afterwards, the common method of forming those artificial fixers of the electrical fluid, was to make use

of

of braſs or iron filings, inſtead of Liquids, and to coat the outſide of the Phial with a thin plate of Lead, which was found to be ſtill better.

248. But the moſt commodious way is to line the inſide of the Phial with Gold-leaf, *&c.* — and to coat it with Tin-foil, thin Lead, or the like, and to faſten ſome Tinſel-fringe or fine wires to the lower end of the Cork-wire within the Phial, ſo as to reach to the Gold-lining, by which means the electrical Fire is convey'd to it from the revolving rubb'd Glaſs.

249. From the foregoing, and many other Experiments, we learn that altho' the electric matter, when obtain'd, ſhews the greateſt reluctance to its being brought into contact with a Glaſs or any other electrical Body, and when non-electrical Bodies are electriſed, the accumulating Æther ſhews the greateſt propenſity to eſcape from them to the *Earth*, yet, what is ſtrange, and what one would not be inclined to expect is, that when an electric *per ſe* is excited by attrition, it then eſcapes from denſe Bodies *to* the *rubb'd* electric.—— A moſt remarkable inſtance of this kind we find exhibited by Mr. *Rackſtrow*'s ſulphur Globe, which, when excited by rubbing, if the fingers of a Perſon were held over it, and even at three Inches diſtance, ſtreams of fire were emitted from all their pores, and as it ruſhed upon the Globe, it made ſuch a hiſſing noiſe, and gave a light ſufficient to ſtartle the Perſon who made the

Experiment *. Mr. *Rackſtrow*'s Eſſay, p. 51. ——Hence it is evident, that when a Glaſs is excited by attrition, it receives a ſupply from the Earth. —— A ſimilar Phænomenon happens when a glaſs Body is otherwiſe electriſed, as will appear by examining the manner of charging the Leyden Phial or glaſs Receiver.

250. The ſeveral Properties of that artificial Fixer of the electrical Fluid are ſo very ſingular and aſtoniſhing, that I have beſtowed no ſmall time and pains in ſearch of the Rationale. What approximations I may hope to have made towards the diſcovery of it, I ſhall endeavour to lay down in the briefeſt manner the ſubject will admit of: And firſt, concerning the manner of charging it.

251. *Firſt.* Let A, and B, repreſent two Perſons, and let A be electriſed on the Reſin-cake, while B ſtands only on the floor.

252. *Secondly.* Let a Saſh-pane properly gilded on both ſides be held between them with its plane in a perpendicular poſition, and an edge of it towards each Perſon, that ſo the two ſides of the Pane may the more eaſily be view'd at once.

253. *Thirdly.* If each Perſon approach a different ſurface of the Pane with a finger, at nearly equal diſtances, when they are about half an inch from the ſurface, a ſpark will dart

* The truth of this cannot be doubted, it being one of the many Experiments he exhibited in Public,

from

from the finger of each to the Glaſs.——This is perform'd ſo inſtantaneouſly as to appear as one ſingle ſpark, i. e. from the electriſed finger of A thro' the thin Glaſs to the unelectriſed finger of B; but the effects ſhew the contrary: For were this the caſe, the Pane would not be affected thereby, whereas a few of thoſe operations charge it. It will as plainly appear that the *Phial* is charged the ſame way. For if a gilded Phial be ſet on an electric Cake, and A and B approach with their fingers, the one near the Cork-wire, and the other near the coating, when they are at the proper diſtance, ſparks will dart from each finger at the ſame inſtant, and the Phial will be charged as the Pane was before.

254. But what is moſt remarkable is, that though it be found neceſſary to electriſe both ſides of the Pane or Phial before it will produce the deſired effect; yet if both ſides are electriſed from the Machine or from two different Machines, it is of no more effect than if only one ſide of it was electriſed.

255. The moſt commodious way of managing the Phial is to take it in the hand, for by that means the Experiments will be more eaſily made, and the Effects more viſible, than when it hangs on the prime Conductor, and conſequently may be explain'd in a more eaſy and familiar manner; for A being electriſed, his hand which holds the Phial is, with regard to the Phial, the prime Conductor, not only

when

when he holds it by the Cork-wire, and by that means electrifes the infide, but if inftead of that he hold it by the coating, that only will be electrifed. ——Firft then, if he take it by the Cork-wire, it will be in the fame fituation as the gilded Safh-pane was, when A laid a finger on one fide only, that is, fince he will not be convulfed by bringing his other hand to the coating; but if he remove that hand from the coating, and B on the floor lay on his hand or finger, it will foon be fufficiently charged; for if after that A lay his finger to it again, he will then be fhock'd as ufual.—— The fame effect will follow, if inftead of holding the Phial by the wire, he take it by the coating, and hold it ever fo long in his hand, the coating only will be electrifed; for if after that he bring his finger to the wire, he feels nothing; but if B, ftanding on the floor, lay on his finger, the Phial is then very foon compleatly charged. For if A put his finger to it again, he is then convulfed. So that in either cafe, the Phial, according to Dr. *Franklin*, was electrifed *plus* and *minus*, i. e. firft, when A held it by the Cork-wire the infide was electrifed *plus*, and the coating *minus*; and fecondly, when he grafped it by the coating, *that* was electrifed *plus*, and the infide *minus*, or in a ftate of want: In either cafe the Phial could never be charg'd till the other furface of it was furnifh'd from the hand of B on the floor.

256. In like manner if B on the floor takes

the Phial into his hand, either by the Cork-wire or by the coating, the ſame effects will follow: If by the coating, the inſide will be electriſed if A lay a finger on the wire; for after this B will receive the ſhock, if he bring his other hand to the wire; and the ſame effect will be produced, if inſtead of his holding it by the coating, he ſhould hold it by the wire; for then A electriſes the coating by laying his finger on that.

257. Hence the ſimilarity of the Phial and gilded Saſh-pane: From either of which, a Phænomenon is exhibited, which perhaps, was hardly thought of before, namely, that when the glaſs Receiver is properly charged, one ſide of it is actually electriſed immediately from the Earth, thro' the Chain or other non-electrical Bodies communicating with it, which, if it be not a diſcovery with reſpect to others, yet I can with truth aſſure the Reader, that I never met with the leaſt hint of it in any Author: On the contrary, moſt Perſons explain it as paſſing the contrary way, *viz. from* the coating of the Phial through the Chain *to* the Floor; and by that means, inſtead of rendering the ſubject more intelligible, have involv'd it in ſtill greater obſcurity: Conſequently, while we proceed on falſe Principles, ſo long the Experiments will be neceſſarily irreconcileable.

CHAP.

CHAP. XII. PART I.

SECTION 258.

The Manner how *the* Shock *in the* Leyden Experiment *is* generated *and* propagated.

HAVING carefully advanc'd thus far, on what 'tis preſumed will be allow'd to be ſufficient evidence; ſince there is nothing either ſtrain'd, feign'd, or arbitrary: No other Properties or Qualities are aſcribed to this Æther than what are plainly diſcover'd in it, moſt of which were foretold by Sir Iſaac *Newton* many Years ago; particularly firſt, *that it is much like Air in all reſpects, but far more ſubtile.* See his Letter to Mr. *Boyle.* Secondly, *That it lies hid in the pores of all groſs Bodies,* in the manner foretold in the laſt Paragraph of his Principia: And almoſt all Experiments are on his ſide and loudly proclaim the ſame Properties, which are ſo obvious, that whoever is converſant with them, or will but take the leaſt trouble to inform himſelf, can neither miſs finding ſuch a fluid to exiſt in the pores of Bodies, nor after he has *pumped* it out*,

* We know ſays Dr. *Franklin*, that the electrical Fluid is *in* common matter, becauſe we can *pump* it *out* by the Globe or Tube, p. 53. of his Letters.

with

with the electric Machine, can he easily be ignorant of its inherent Rarity and Elasticity. —— I shall therefore endeavour next to investigate the means by which that inconceivable violence is generated in the Leyden Experiment by the same cautious method.

259. In order to perform so difficult a Task, which hath hitherto baffled every attempt, I shall here collect some Positions, which have been already proved, and try how far they are capable of assisting me in the arduous Undertaking.

260. *First.* That the constituent parts of Æther, contain'd in Bodies, consist of all degrees of rarity, or rather all degrees of purity, agreeable to the nature of it, as describ'd by Sir Isaac *Newton* in his foremention'd Letter to Mr. *Boyle*.

261. *Secondly.* That the most pure, rare, and subtile part of it, is also the most elastic and active; and that this rule holds equally true in all the intermediate gradations from the most pure æthereal part, down to the grossest common Air.

262. *Thirdly.* That the subtile Æther contain'd in the pores of the most *perfect* non-electrical Bodies is *perfectly* loose, free, and fluid, such as Metals, Water, Animals, and green Vegetables, especially the two former; and in various cases, is found, from the strictest Observation, to move freely out, provided it be for an equal quantity.

263. *Fourthly.* That in all degrees of Attri-

tion a proportionate degree of Expanſion is exerted, at leaſt to a certain height; and ſince the homogeneous particles mutually repel each other, and conſequently the maſſes compoſed of them, the expanſive force therefore of the pure Air or Æther is ſo much ſuperior to the expanſive force of the *common* Air, that the Limits occupied by a maſs or aſſemblage of the former, ſuch as the accumulations on Bodies when electriſed, muſt conſequently, by being ſo much more elaſtic than the latter, buoy it up, that is, repel and bear it away from the Body on which the Æther is accumulated : By this means the equilibrium is deſtroyed, and in the ſame proportion as the rarity of the Æther within thoſe limits exceeds that of the common Air which ſurrounds it ; and conſequently, that thoſe rare limits may be conſider'd as ſimilar to a vacuum with reſpect to the Air, eſpecially, ſince the effects of almoſt all electrical Experiments verify the Facts, and therefore juſtify the concluſion.

264. *Fifthly*. That the Æther is firmly fix'd in all the parts of Amber, Glaſs, Reſin, Wax, and all other Bodies, term'd original Electrics, See *Sect.* 204.

265. *Sixthly*. That when thoſe ſubtile particles are irritated by Attrition or Friction of any kind (which is the caſe when the Glaſs is rubb'd, ſince by being fix'd in all parts of the Glaſs it is incapable of eſcaping from the Inſtrument of friction) we can always obſerve

from

from the effects of every ſuch Experiment, that the Equilibrium of the adjacent Air is deſtroy'd, and that the foremention'd *Pneuma* or *Spirit* is inceſſantly paſſing into ſuch rarefied limits from all the ſurrounding parts, and by that means impel light Bodies into them*.

266. A ſmall Attrition of the Glaſs is ſufficient to produce thoſe Effects, as appears from Mr. *Boyle*'s Experiment with a piece of Amber when only laid in the Sun, or even a Glaſs when warm'd by the fire, which by that means became electrical. See Vol. I. p. 400. of Mr. *Boyle*'s Works, abridged by Mr. *Shaw*.

267. If then ſo inconſiderable an Attrition as the Sun-beams ſtriking on the ſurface of thoſe Bodies where the Æther is fix'd, be yet ſufficient to cauſe ſuch an emanation, or as he terms it, an effluvia emitted by the glaſs, we have the leſs room to admire, if the ſame emanation be extended to a much greater diſtance from the glaſs when the Æther in the ſurface of it is irritated by *violent Friction.*——But the effects of thoſe effluvia or emanations extended from the fix'd Æther in the glaſs, are not only viſible on the rubb'd ſide of the glaſs, but extend them-

* From the effects of the Experiments, thoſe Limits appear to be the moſt rare and elaſtic of all, at the very ſurface of the electriſed Body, whether it be the rubb'd Glaſs, or whether it be any other thing electriſed; and that from the ſurface of the electriſed Body to the extremity of thoſe Limits, ſuch rarity and elaſticity gradually decreaſe.

or with ever so many turnings and windings.

274. The sudden and violent shock is propagated throughout the non-electric Circuit by means of the continuity of the particles of the Æther contain'd in it from one end to the other; all moving each other in the same instant, and notwithstanding the irregularity of the Circuit, yet the contain'd Æther is mov'd in a similar manner and with the same freedom as every part of the Circumference of a solid circle or wheel is conceiv'd to be mov'd, were such wheel to be turn'd on its axis; for otherwise it would be difficult to imagine how a motion could be communicated to every part of the largest Circuit possible, as instantaneously as to the smallest.

CHAP. XIII. PART I.

SECTION. 275.

The Fallibility *of the greatest* Philosophers, *and* Imperfection *of all* human Knowledge.

ALTHO' the existence of a subtile Medium has been clearly demonstrated and realiz'd, and all its Properties plainly proved by undoubted Evidence, *viz.* that of most, if not of all our Senses; tho we find by the Effects of Experi-

ments

ments that every groſs Body is replete with it; and tho' we have availed ourſelves of the Labours and Induſtry of thoſe eminent Naturaliſts who went before us on this Subject, yet with all theſe Advantages we had fallen ſhort of ſufficient *Data* whereby to render this grand principle ſo intelligible as to be able to apply it to any uſeful Purpoſe, had it not been for the two moſt remarkable hints of the great Sir Iſaac *Newton*, *viz.* that contain'd in the concluding Paragraph of his Principia, and that in his Queries or Queſtions contain'd in his Optics. The former of which informs us in expreſs terms that a ſubtile Medium or Spirit exiſts in the pores of all groſs Bodies; and the latter, that the ſame ſubtile Agent or Principle is poſſeſſed of two moſt wonderful eſſential Properties or Qualities, *viz.* thoſe of Rarity and Elaſticity in the higheſt degree imaginable. Had theſe hints, I ſay, been wanting, we muſt ſtill and perhaps for a long time to come have been quite in the dark as to many things, which by means of thoſe aids of his are render'd clear and intelligible; and the Engliſh Nation may (now eſpecially) juſtly boaſt of him as a Genius who has exceeded all others in the diſcovery of the moſt ſublime and important Philoſophical Truths*.

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* Theſe I may properly call *Truths*, ſince nothing was ever more clearly verified by Experiment, than the exiſtence not only of the ſubtile Medium itſelf, but likewiſe all thoſe natural Qualities which are aſcribed to it by Sir *Iſaac*. 276.

276. But notwithstanding my great Regard for Sir *Isaac*'s Abilities, yet at the same time I must confess, I am not so blind an Idolater at his shrine as to think him infallible, and not liable to mistakes in common with other Men: To carry it farther would be a *Zeal* without *Knowledge*.

277. 'Great Names certainly deserve great Respect; but a servile veneration prevents the Advancement of Science. There may be indeed a want of decency and candour, (which, I hope, I shall not be justly chargeable with,) in the manner of imputing Error and Inconsistencies to great Men; but there is certainly none in the Imputation itself, if founded on Truth. I look, for instance, upon the Authority of Sir Isaac *Newton* to be as far above all other Philosophers, as that of a Pope above a whole Conclave of Cardinals; but yet I hold the Philosophical Infallibility of the one, just as much as I do the Spiritual Infallibility of the other, and conceive those who implicitly credit the former to be as much bigotted to prejudice, as those who place implicit belief in the latter.

278. Error is an inseparable Appendage of humanity, and Men are worthy of Esteem according as they employ the talents which the great Author of Nature hath been pleased to bestow upon them, notwithstanding the mistakes they may inadvertently and involuntarily have fallen into.——To instance in *other* English Philosophers; neither the indefatigable

Mr.

Mr. *Boyle*, nor the worthily renown'd Lord *Bacon*, notwithſtanding their admirable Talents and uncommon Attainments, nor indeed any other Individual whatſoever can plead an exemption from this univerſal frailty of our preſent imperfect ſtate.

279. Dr. *Halley*, for example, was juſtly allow'd to be a moſt acute and moſt extenſively learned Man, [this is the Character given of him by Sir Iſaac *Newton* himſelf *] and was eſteemed by all an able Mathematician, Philoſopher, *&c.* and nothing can more evince an enterpriſing Genius than thoſe two grand Schemes of his, which he yet unſuceſsfully attempted; one of which was to predict the time of the return of a Comet, that was not obſerv'd to appear according to his prediction; and the other that of a method to aſcertain the true diſtance of the Planet Venus from the Earth, (by means of the tranſit of that Planet over the Body of the Sun in the Year 1762,) and conſequently the diſtance of the Sun and the other Planets, in which he alſo was miſtaken. —— The ſcheme or method by which he propoſed to effect the latter, appears to have been the following:

280. That if the path of the Planet over the diſk of the Sun were accurately taken at parts of the Earth far diſtant from each other, the Track of the Planet acroſs the diſk muſt ne-

* See the Preface to his Princip.

ceſſarily appear at different parts of it; and by that means afford a parallax ſufficient to aſcertain the diſtance of it; but the deſir'd effect does not appear to have been produc'd.

281. Quære. Whether the Phænomenon was capable of affording a ſufficient parallax, and for the following reaſons? Firſt, The greateſt diſtance of any two places of Obſervation on the Earth's ſurface can be only a few thouſand Miles, ſince they can be but 8000 diſtant if they were diametrically oppoſite, conſequently 6000 Miles muſt be eſteem'd an ample allowance. The neareſt diſtance of the Earth to the Planet Venus is upwards of 20 millions. Now 6 thouſand is contained in 20 millions no leſs than 3333 times, in which caſe the parallax will be ſcarce a ſingle minute of a degree, which muſt conſequently be too ſmall to make any conſiderable diſcovery:

282. To illuſtrate the above Computation, let me farther remark that the magnitude of that Planet is allow'd by the moſt accurate Aſtronomers to be nearly equal to the magnitude of the Earth; and yet by means of the great diſtance it appears not much greater than a mere lucid point: And if that, by means of the diſtance, dwindle into a point, the Earth being of the ſame magnitude and at the ſame diſtance, muſt ſeem as a point alſo; conſequently viewing the ſame object from any different part of a point, can make no material difference.——I ſay not this with the leaſt view of detracting from that great

great Man's exalted Character: He muſt ever ſtand as a bright Luminary to the Philoſophical world; but yet, like all other Men, muſt be allow'd to be liable to Error, as the above Obſervation rationally evinces.

283. It muſt be natural to ſuppoſe, that while I was writing down my Sentiments on the ſeveral Experiments made at the electrical Apparatus relative to this ſubtile Medium, that I ſhould carry my thoughts ſtill farther, and reflect on the great office and various uſes of this extenſive and univerſal Agent; particularly when I conſider'd, Firſt, that nothing was made in vain, and that all things on examination are found in juſt proportion of number, meaſure, *&c.* The ſeveral Phænomena, or natural motions of the heavenly Bodies, for inſtance, are perform'd with mathematical exactneſs, as Sir Iſaac *Newton* in his Principia has clearly demonſtrated.

284. *Secondly.* The ſeveral Planets in their reſpective Orbits deſcribe equal Areas in equal times, ſecondary as well as primary: *Thirdly.* The ſquares of their ſeveral Periods are ever as the cube of the diſtances from their reſpective Centers: And *Fourthly.* Not only the Force of Gravity is diſcover'd to be in an inverſe ratio of the ſquare of the diſtance, but that of Heat and Light alſo, even the Light of a common Lamp or Candle*.——These Things con-

* See Dr. *Gregory*'s elements of Aſtronomy Vol. 1ſt p. 506. where the ſame is mathematically demonſtrated.

fider'd and an infinity of others, how great and extenfive, I fay, muft be the Purpofes which fuch an univerfal Agent was ordained to ferve!

285. Hence then fo long as we were ignorant of the exiftence of fuch a powerful Inftrument of Nature, it muft be morally impoffible that the beft Syftem of Philofophy that was ever exhibited to the world fhould be free from grofs Errors and infurmountable Difficulties, when the very exiftence of that which now plainly appears to be the firft fpring of mechanical action was unknown. If then we have all along proceeded on falfe Principles, have we any reafon to wonder at the erroneous Confequences which have enfued?

286. Since therefore the want of the Knowledge of the exiftence of that Agent muft neceffarily be the caufe of innumerable Errors, and thofe Errors the occafion of the moft infuperable Difficulties, and Philofophy on that account be left dark and myfterious; will not the introducing of it furnifh out a Philofophy of a much more fatisfactory and favourable afpect?

287. If fuch natural Reafoning then fhould appear juft, would not the cultivation of this active Agent feem rational; fince then, new Light in all probability would be reflected on the Obfcurity with which the received Syftems of our prefent Philofophy abound, and new Difcoveries would be frequently darting in upon us, could we but once prevail with ourfelves to fet heartily about a thorough and ftrict exami-

nation of this electric and elastic Fluid, especially as it proves to be true Fire.

288. The Discovery of a subtile Medium, which we have so happily made, shews it to be the same mechanical Agent that Sir Isaac *Newton* so much wished for when he wrote his Principia.

In the Preface to that Treatise, after the Author had been informing us of the method he had taken to explain the celestial Phænomena, and had, by that means, pointed out the different Forces, as he called them, which were the causes of those appearances, he adds, 'From 'these Forces, by other Propositions which are 'also mathematical, we deduce the motions 'of the Planets, the Comets, the Moon, and 'the Sea. I wish we could derive the rest of 'the Phænomena of Nature by the same kind 'of reasoning from *mechanical Principles*. For 'I am induced by many Reasons to suspect 'that they may all depend upon certain Forces 'by which the particles of Bodies, by some 'Causes hitherto unknown, are either mutu-'ally impelled towards each other and cohere 'in regular Figures, or are repelled and recede 'from each other; which Forces being un-'known, Philosophers have hitherto attempted 'the *Search of Nature* in vain. But I hope the 'Principles here laid down, will afford some 'Light either to that, or some *truer* method 'of Philosophy.'

289. This Reasoning of Sir *Isaac* confirms the

the foremention'd obſcurities and perplexities attending natural Philoſophy.—— The Force i. e. the active Agent diſcoverable by means of the electrical Apparatus being unknown to Philoſophers when he wrote his Principia, they had always *attempted the ſearch of Nature in vain*.—— That great Naturaliſt, we find, was ſo far from endeavouring to obtrude any Opinion on others, before he was throughly ſatisfied of the truth of it himſelf, that notwithſtanding he had been taking ſuch indefatigable pains in writing that Treatiſe; yet his ardent deſire of ſeeing true Philoſophy eſtabliſh'd cauſed him to expreſs ſome diffidence. ' I hope the Prin-' ciples here laid down,' *&c.*——In Sir *Iſaac's* Time no Medium more ſubtile and elaſtic than the Air had ever been actually diſcover'd, conſequently all that could be ſaid of Æther was for the moſt part conjectural. It was then the current Opinion that there really *was* no Medium more active than the common Air. But what was the conſequence? We are inform'd that Philoſophers had always *attempted the Search of Nature in vain*.———Had Sir *Iſaac* liv'd to ſee his *ſubtile elaſtic Medium* evidently diſcover'd, we may be very certain his enterpriſing Genius would never have ſat for 20 Years ſupinely, as if nothing had happen'd, or as if he had thought, as ſome of his Diſciples ſeem to do, that the grand Diſcovery was not worth cultivating.

CHAP.

CHAP. XIV. PART I.

SECTION 290.

The Use of pointed Iron Rods *to preserve High Buildings, Ships, &c. from* Lightning. *Dr.* Franklin's Paste-board Tube, *and* artificial Kite.

HAVING from a Series of Experiments in the former Chapters, I hope, sufficiently proved the truth of Sir Isaac *Newton*'s Opinion, concerning a subtile Æther, existing in the pores of all gross Bodies, i. e. in all *minute* Spaces, I shall now proceed to try what Evidences I can produce, in support of what he has advanc'd concerning the *universality* of the same Medium in all *open* Spaces.——The principal of which, I procured from my intimate acquaintance with the Letters of the ingenious Dr. *Franklin.* The first of which contains a curious electrical Experiment, that leads on to others of a more physical Nature, which indubitably proves, that the electrical Fluid and the Fire of Lightning are identically the same Substance; since they invariably assume each others Offices and Properties, as will more fully appear from the following Extract, which is a literal Transcript from

from that ingenious *Gentleman's* Letters on that moſt intereſting ſubject, *viz.* Preſervation from the direful Effects of Lightning.

291. ' I have, ' ſays he, ' a large prime Con- ' ductor made of ſeveral thin ſheets of Fuller's ' paſteboard, form'd into a Tube near 10 feet ' long and a foot Diameter: It is cover'd with ' *Dutch* emboſs'd Paper, almoſt totally gilt. ' This large metallic Surface ſupports a much ' greater electrical Atmoſphere than a Rod of ' Iron of 50 times the weight would do: It is ' ſuſpended by ſilk lines, and when charg'd, will ' ſtrike at near two Inches diſtance, a pretty ' hard ſtroke, ſo as to make one's knuckle ach. ' Let a Perſon, ſtanding on the floor, preſent ' the point of a needle at 12 or more Inches ' diſtance from it, and while the needle is ſo ' preſented, the Conductor cannot be charged, ' the point drawing off the fire as faſt as it is ' thrown on by the electrical Globe. Let it be ' charged, and then preſent the point at the ' ſame diſtance, and it will ſuddenly be diſ- ' charged. In the dark you may ſee a light on ' the point, when the Experiment is made: ' And if the Perſon, holding the point, ſtands ' upon wax, he will be electrified by receiving ' the fire at that diſtance. Attempt to draw ' off the Electricity with a blunt Body, as a ' bolt of Iron, round at the end and ſmooth, ' (a Silverſmith's iron Punch, inch-thick, is ' what I uſe) and you muſt bring it within the ' diſtance of three Inches before you can do it,

' and

'and then it is done with a ſtroke and crack.
'As the Paſteboard Tube hangs looſe on ſilk
'lines, when you approach it with the punch
'iron, it likewiſe would move towards the
'punch, being attracted while it is charg'd;
'but if at the ſame inſtant, a point be preſent-
'ed as before, it retires again, for the point
'diſcharges it.——Take a pair of large braſs
'Scales, of two or more Feet beam, the cords
'of the Scales being ſilk : Suſpend the beam
'by a packthread from the cieling, ſo that the
'bottom of the Scales may be about a foot
'from the floor : The Scales will move round
'in a circle by the untwiſting of the pack-
'thread. Set the iron punch on the end upon
'the floor, in ſuch a place as that the Scales
'may paſs over it in making their circle: Then
'electrify one Scale by applying the wire of a
'charged Phial to it. As they move round,
'you ſee that Scale draw nigher to the floor,
'and dip more when it comes over the punch;
'and if that be placed at a proper diſtance, the
'Scale will ſnap and diſcharge its Fire into it.
'But if a needle be ſtuck on the end of the
'punch, its point upwards, the Scale, inſtead
'of drawing nigh to the punch and ſnapping,
'diſcharges its Fire ſilently through the point,
'and riſes higher from the punch : Nay, even
'if the needle be placed upon the floor near
'the punch, its point upwards, the end of the
'punch, tho' ſo much higher than the needle,
'will not attract the Scale and receive its Fire,

'for the needle will get it and convey it away, 'before it comes nigh enough for the punch 'to act. And this is constantly observable in 'these Experiments, that the greater quantity 'of Electricity on the pasteboard Tube, the 'farther it strikes or discharges its fire, and the 'point likewise will draw it off at a still greater 'distance.

292. 'Now if the Fire of Electricity and 'that of Lightning be the same, as I have en'deavour'd to shew at large in a former Paper, 'this pasteboard Tube and these Scales may 'represent electrified Clouds. If a Tube of on'ly 10 Feet long will strike and discharge its 'fire on the punch at two or three Inches dis'tance, an electrified Cloud of perhaps 10,000 'Acres may strike and discharge on the Earth 'at a proportionably greater distance. The 'horizontal motion of the Scales over the floor, 'may represent the motion of the Clouds over 'the Earth; and the erect Iron punch a Hill 'or high Building; and then we see how elec'trified Clouds passing over Hills or high 'Buildings at too great a height to strike, 'may be attracted lower till within their strik'ing distance. And lastly, if a Needle fixed on 'the punch with its point upright, or even on 'the floor below the punch, will draw the fire 'from the Scale silently at a much greater than 'the striking distance, and so prevent its de'scending towards the punch; or if in its 'course it would have come nigh enough to 'strike

'ſtrike, yet, being firſt depriv'd of its Fire, it 'cannot, and the punch is thereby ſecured 'from the ſtroke. I ſay, if theſe things are ſo, 'may not the Knowledge of this power of 'Points be of uſe to mankind, in preſerving 'Houſes, Churches, Ships, &c. from the ſtroke 'of Lightning, by directing us to fix on the 'higheſt part of thoſe Edifices, upright Rods 'of Iron made ſharp as a needle, and gilt to 'prevent ruſting, and from the foot of thoſe 'Rods a wire down the outſide of the Building 'into the ground, or down round one of the 'Shrouds of a Ship, and down her ſide till it 'reaches the water? Would not theſe pointed 'Rods probably draw the electrical Fire ſilently 'out of a Cloud before it came nigh enough 'to ſtrike, and thereby ſecure us from that 'moſt ſudden and terrible miſchief?

293. 'Before I leave this Subject of Light-'ning, I may mention ſome other ſimilarities 'between the effects of that, and theſe of Elec-'tricity. Lightning has often been known to 'ſtrike People blind. A Pigeon that we ſtruck 'dead to appearance by the electrical ſhock, 'recovering Life, droop'd about the Yard ſe-'veral days, eat nothing, tho' crumbs were 'thrown to it; but declin'd and died. We did 'not think of its being depriv'd of Sight; but 'afterwards a Pullet being ſtruck dead in like 'manner, and being recover'd by repeatedly 'blowing into its Lungs, when ſet down on 'the floor, ran headlong againſt the Wall, and

'on examination appeared perfectly blind. 'Hence we concluded that the Pigeon alſo 'had been abſolutely blinded by the ſhock.' See Dr. *Franklin*'s Letters, p. 59. 60. *&c.*

294. That celebrated Electrician was ſo firmly perſuaded of the good Effects of pointed Rods, if erected on lofty Buildings, that he put the ſame into Practice as appears by the following extract.

LETTER X.

From Benjamin Franklin, Eſq; *of* Philadelphia, *October*, 19th. 1752.

295. 'As frequent mention is made in the 'News Papers from *Europe*, of the Succeſs 'of the *Philadelphia* Experiment for drawing 'the electric Fire from Clouds by means of 'pointed Rods of Iron, erected on high Buildings, *&c.* it may be agreeable to inform the 'curious, that the ſame Experiment has ſucceeded in *Philadelphia*, though made in a 'different and more eaſy manner, which is as 'follows:

296. 'Make a ſmall croſs of two light ſtrips 'of Cedar, the arms ſo long as to reach to the 'four corners of a large thin ſilk handkerchief 'when extended; tie the corners of the handkerchief to the extremities of the croſs, ſo you 'have the Body of a Kite; which being properly 'accommodated with a Tail, Loop, and String, 'will riſe in the Air like thoſe made of Paper;

'but

'but this being of Silk is fitter to bear the 'wind and wet of a Thunder Guſt without 'tearing. To the top of the upright ſtick of 'the croſs is to be fixed a very ſharp pointed 'wire, riſing a foot or more above the wood. 'To the end of the twine, next the hand, is to 'be tied a ſilk ribbon, and where the ſilk and 'twine join, a Key may be faſten'd. This Kite 'is to be raiſed when a Thunder Guſt appears 'to be coming on, and the Perſon who holds 'the ſtring muſt ſtand within a Door, or Win-'dow, or under ſome cover, ſo that the ſilk 'ribbon may not be wet; and care muſt be 'taken that the twine does not touch the frame 'of the Door or Window. As ſoon as any of 'the Thunder Clouds come over the Kite, the 'pointed wire will draw the electric fire from 'them, and the Kite with all the twine will be 'electrified, and the looſe filaments of the twine 'will ſtand out every way, and be attracted by 'an approaching finger: And when the rain 'has wet the Kite and Twine, ſo that it can 'conduct the electric fire freely, you will find 'it ſtream out plentifully from the Key on the 'approach of your knuckle. At this Key the 'Phial may be charged; and from electric fire 'thus obtain'd, Spirits may be kindled, and all 'the other electric Experiments be perform'd, 'which are uſually done by the help of a 'rubb'd glaſs Globe or Tube; and thereby 'the ſameneſs of the electric matter with that 'of Lightning completely demonſtrated.'

CHAP.

CHAP. XV. PART I.

SECTION 297.

Particular Accounts of the Electrical Kite *of M. de* Romas; and *of the* Death *of Professor* Richmann.

M. de *Romas*, Judge of the Presidial Court of *Nerac* in *Aquitain*, and corresponding Member of the Royal Academy of Sciences at *Paris*, says, 'Being willing 'to try what would be the Effect of electrifying 'a Body raised to a considerable height in the Air, 'I prepar'd a Paper Kite seven Feet five Inches 'high, and three Feet in its greatest breadth, its 'surface being about eighteen square Feet.'

298. 'The first trial I made with my Kite 'was on the 14th of *May* 1753; but tho' my 'erect Bars were several times well electrified 'from the Atmosphere that day; yet I could 'not excite the least spark from the Kite, tho' 'I knew for certain, that it was perfectly in'sulated. After divers Reflexions, I concluded, 'that the reason why I could excite no sparks 'from the string of the Kite, was, that as there 'was little rain, the hempen string was not 'sufficiently wetted to make it a good Conduc'tor, unless the Electricity were exceeding 'strong.'

299.

299. ' The Day promiſing ſo well, I drew
' down my Kite, and oil'd it all over, as a ſe-
' curity againſt rain, and ran a ſmall braſs wire
' about the ſtring from one end to the other;
' but this additional Improvement to my Ap-
' paratus took up ſo much time, that I could
' not purſue my trials any farther that day.'

300. ' After ſeveral unſucceſsful Attempts
' on the 7th of *June*, when it thunder'd in the
' Weſt, about one in the afternoon, I made a
' ſhift about half an hour after two to raiſe my
' Kite at leaſt 550 Feet high above the ground,
' it reeving out 780 Feet of ſtring, which made
' an angle of near 45 Degrees with the Horizon.'

301. ' The Wind ſeem'd to increaſe, which
' gave me hopes that the Kite would not fall.
' I therefore tied a ſilk Lace of three feet and
' an half long to the lower end of the ſtring,
' and to the lower end of the Lace I faſten'd
' a kind of ſtrong Pendulum, whoſe weight
' was a large Stone, under a Pent-houſe, on
' the outſide of the Town. Beſides this, to the
' ſtring of the Kite near the ſilk Lace, I hung
' a tin Tube of an Inch diameter, and a Foot
' long, from whence to draw ſparks as ſoon as
' the Kite ſhould become electrified. The rea-
' ſon for my faſtening the ſilk to a Pendulum,
' was to prevent its dragging on the ground,
' and thereby taking up duſt, in caſe the wind
' ſhould ſlacken, whilſt the Pent-houſe ſecured
' it from rain, and to regulate the jerks which
' might be occaſion'd by ſudden Guſts of
' wind.'

302. 'After theſe diſpoſitions I was to try 'if the tin Tube afforded any tokens of Elec- 'tricity; but as it was prudent, for a reaſon 'which will appear hereafter, not to approach 'the tin Tube with a finger, a key, or any 'thing of that nature, I prepar'd a little In- 'ſtrument better ſuited to the purpoſe. To 'one end of a glaſs Tube, twelve Inches long, 'and a quarter of an Inch diameter, I fitted a 'little tin Socket, rounded at the end like a 'Woman's Thimble, and from this Socket 'hung a little wire, which touch'd the ground, 'when I offer'd to draw a ſpark. The end of 'this Contrivance was to enable me to excite a 'ſpark without any diſagreeable ſenſation or 'ſhock in the hand which held the glaſs Tube, 'thro' which the electric matter will not paſs; 'but without the communication with the 'ground, by the wire, ſcarce any ſpark could 'be drawn from the tin Tube. So that laying 'hold of the end of the glaſs Tube, and taking 'care that the wire dragged on the ground, I 'judged I might without any inconvenience, 'by advancing the butt end of the Socket to- 'wards the tin Tube, excite the largeſt and 'brighteſt ſparks. And indeed every thing not 'only ſucceeded to the utmoſt of my expecta- 'tion, but I was beſides convinced in an ex- 'traordinary manner, how neceſſary a precau- 'tion I had taken.'

303. 'The ſparks at firſt were not unlike 'thoſe which we get by means of a good

Globe,

'Globe, and were occaſion'd by ſome ſmall
'Clouds detach'd from the grand ſtorm. And
'as at this very time there was no appearance
'of any thing very extraordinary, I laid aſide
'the little glaſs Inſtrument, which hereafter I
'ſhall call the Exciter, and drew ſparks ſome-
'times with a key, and ſometimes with my
'bare finger. The By-ſtanders encouraged by
'my Example did the like, and there was
'ſcarce any of them that did not draw ſome
'ſparks. Soon after this the Electricity was
'interrupted, the ſmall Clouds being paſſed
'over.'

304. 'The Electricity being again reviv'd,
'after a pretty long intermiſſion, every one re-
'ſum'd the former Exerciſe with fingers and
'keys, or their Swords; and I attempting the
'like the next moment with the knuckle of
'the middle finger of my right hand, received
'ſo terrible a ſhock, that I felt it in all the
'Fingers of that Hand, in my Wriſt, Elbow,
'Shoulder, Abdomen, both Knees, and the
'Malleoli of my Feet; ſuch a ſhock, as I am
'apt to think, was never produc'd by the beſt
'Globe, and two large glaſs Jarrs coated after
'Dr. *Bevis*'s manner, or the exhauſted Phial
'of M. Abbe *Nollet*.'

503. 'Several of the Company, who obſerv'd
'the convulſive motions I was in, were ſatisfied
'of the violence of the Commotion, and yet
'ventur'd to join hands, as in the Leyden Ex-
'periment, but without forming a Circuit

'(which could not be done but with a Phial)
'and the ſhock was felt as far as the Feet of the
'fifth Perſon.'

306. 'I relate theſe facts, in hopes that Perſons uſed to electrical Experiments may draw ſome light from them for explaining the neceſſity of forming the Circuit in the noted Leyden Experiment.'

307. 'When theſe Gentlemen had inform'd me of what they felt, I adviſed them not to expoſe themſelves any farther. The Storm advanced, and grew more and more violent; for tho' one drop of rain had not fallen, there was over the Zenith of the Kite, and near 60 Degrees round it, black Clouds which made me dread a ſudden Guſt of Electricity, which might bring on ſome fatal accident.'

308. 'I took myſelf the advice I had given to others; I look'd upon it as unſafe to draw any more ſparks, without the Exciter. Having brought it within the diſtance of four Inches from the tin Tube, a ſpark iſſued out full an Inch long, and two lines thick. Returning a ſecond time, I drew a ſecond at the diſtance of five or ſix Inches at the leaſt, which was two Inches long, and thick in proportion. In a word, I drew four or five more, much of the ſame Dimenſions. Some little time after they appear'd not ſparks, but rather flaſhes of fire, which were excited at the diſtance of a foot, being at leaſt three Inches long, and a quarter of an Inch thick; the

'ſnap-

'snapping of these was heard above two hun-
'dred paces.'

309. 'Whilst I remain'd in this situation, I 'felt, as it were, a Cob-web on my Face, tho' 'I was above three Feet from the string of the 'Kite. I did then believe that it was not safe 'to stand so near, and called aloud to all the 'Company to retire, as I did myself about two 'Feet.'

310. 'Thinking myself now secure enough, 'and not being incommoded by any Body very 'near me, my first care was to take notice 'what passed among the Clouds, which were 'immediately over the Kite. I could perceive 'no Lightning either there or any where else, 'nor scarce the least noise of Thunder, nor any 'Rain at all. The Wind was West and pretty 'strong, which raised the Kite at least 100 'Feet higher than in the first Experiments.'

311. 'Afterwards casting my Eyes on the 'tin Tube, which was about three Feet distant 'from the ground, I saw three straws, one of 'which was about a Foot long, a second four 'or five Inches, and a third, three or four Inch-'es, which Straws being erect, and touching 'the ground with their lower extremities, 'performed a circular dance like Puppets, un-'der the tin Tube, without touching one ano-'ther.'

312. 'This little Spectacle, which much 'delighted several of the Company, lasted 'about a quarter of an hour, after which some

'ſtring was diſengag'd from the Pent-houſe, 'the Perſon that held it, felt ſuch a ſtroke in his 'hands, and a commotion through his whole 'Body, as oblig'd him inſtantly to let go, and 'the ſtring dropping croſs the Feet of ſome 'others, produced in them alſo a ſhock, tho' 'much more tolerable.' See *Gentleman's Magazine* for *Auguſt* 1756. p. 378.

318. In the *Gentleman's Magazine* for *February* 1763. p. 69. We have an Account of another Kite flown by the ſame Perſon, from which ſtreams of fire were produced an Inch thick, and 10 Feet long, on *Auguſt* 26th. 1756.

319. Mr. Profeſſor *Richmann*, of the Imperial Academy of Sciences, at *Peterſbourgh*, who was killed whilſt he was making an electrical Experiment, had a tall Iron Rod erected on the higheſt part of his Houſe, according to Dr. *Franklin*'s Method; the lower end of which was firmly fix'd in a glaſs Stand: To this Rod a Chain of metal was connected, and brought down into his Chamber, where was an electrical Machine.

320. The Chain was ſo ſupported with ſilken ſtrings, as to touch no part of the Building. When he judged the Air to be replete with electrical Fire, he frequently made Experiments in his Chamber with that Apparatus in conjunction with his electrical Machine.

321. '*May* 31ſt. 1753. The electrical Fire 'exploded with ſuch a Force from the Appa'ratus on his Houſe, as to be heard at the diſ-

tance

' tance of three Rooms from his Chamber.'

322. 'And on the 6th. of *August* following, ' The Profeſſor, with Mr. *Sokolow*, Engraver ' to the Academy, were obſerving the Effects ' of Electricity on his Gnomon, or Electrome- ' ter, during a Thunder ſtorm: But as Mr. ' *Richmann* was not apprehenſive of the great ' quantity of Fire accumulated on the Appa- ' ratus, from the vaſtneſs of the cauſe, being ' unfortunately too near, he was inſtantly ſtruck ' dead.—— Mr. *Sokolow* ſaw a Globe of Fire ' as big as his fiſt, burſt forth from the Appa- ' ratus to Mr. *Richmann*'s Forehead, who, at ' that time was the neareſt non-electric com- ' municating with the floor, and about a Foot ' from it, obſerving the Index of his Electro- ' meter. The Globe of Fire was attended with ' a Report, as loud as that of a Piſtol. The ' Door-caſe was ſplit half through, and the ' Door torn off, and thrown into the middle ' of the Chamber. His Clock, which ſtood ' in the corner of the next Room, was ſtopp'd, ' and the Aſhes from the hearth were thrown ' about the Room. Half of the glaſs Veſſel, ' which contained the metal filings, was broken ' off, and the filings ſcattered alſo about the ' Room.—— Laſtly, many Perſons without ' Doors declared their having ſeen the Light- ' ning ſhoot from the Cloud to the Profeſſor's ' Apparatus at the top of the Houſe.'

323. Since, by a variety of Experiments made with tall pointed iron Rods erected on the

tops

tops of lofty Buildings, it evidently appears that the Fire obtained by that means, is the ſelf ſame with that obtained by the electrical Machine, the Effects produc'd by both being quite ſimilar; and ſince an inſtantaneous Reſ-toration of the Equilibrium among all its parts, is obſerved to be one of its moſt prevailing Properties, it may be reaſonably ſuppoſed that the flaſh of Lightning obſerved to break forth to the Rod on the Houſe-top, was an Effect of the ſame Property, *viz.* that of reſtoring the Equilibrium, and that it happen'd at the very Inſtant that ſo great a quantity burſt forth at the lower end of the Apparatus to M. *Richmann*'s Head.

An Experiment, by way of illuſtration, may be made at the electrical Machine, thus:

324. Let an iron Rod be ſupported with ſilken Strings, ſo that the upper end of it may come very near to the excited Apparatus of Wires, &c. of the electrical Machine, but not quite in contact with it; and the ſuſpended Rod thus ſupported, will be electriſed equally with the Apparatus, by being near it: If then a Spark be drawn from the lower end of the Rod, the propenſity to reſtore the Equilibrium is ſo remarkable, that an equal Spark will appear at the ſame Inſtant between the upper end of it, and the excited Apparatus: And it is well known that equal Effects would be produced were ſuch an Apparatus of ſuſpended Wires and Rod, carried from a Machine, to

the

the top of the highest Hall or Stair-case, or to any point of elevation whatever. Can it then be reasonably doubted, whether the flash of real Lightning that was observ'd to break forth to the iron Rod at the top of Professor *Richmann*'s House, was at the very instant he was struck Dead with the Ball of Lightning at the bottom?

325. 'This Catastrophe, it is presum'd, 'would not have happen'd, had the Chain, or 'any other part of that Apparatus from the 'House-top, touch'd the Building, as the Elec'tricity would have been readily communicated 'thereby to the Earth.' See *Gentleman*'s *Magazine* for *July* 1755. p. 312.

The CONCLUSION of PART I.

SECTION 326.

FROM the foregoing Reasoning it is evident that I have shewn no partial regard to my own Experiments more than to those of others, as I was well satisfied they came from approv'd Authors, or else were such Experiments as are well known; my design in exhibiting them being to evince, by plain demonstration, the actual Existence of such a First Principle, which though it has been too long either doubted or denied, yet must be admitted and allow'd, before Philoso-

phy can ever flow naturally and ſmoothly on, as if in its true and proper Channel, and before we can proceed to deduce any Thing *a priori* *. Theſe Conſiderations convinc'd me of the abſolute neceſſity of a ſufficient number of experimental Proofs of the Exiſtence and wonderful Properties of this Principle, and for theſe Reaſons and ſome other I found myſelf under a kind of neceſſity of reconſidering ſome Experiments which I had given the World in my former Publications, in order,

327. *Firſt.* To correct Errors, which, I have ſince found, I had then fallen into.

328. *Secondly.* Altho' in my former Eſſays on Electricity I always kept my Eye fix'd on that which plainly appear'd to be the moſt principal Object, *viz.* that the electrical ſubtile Fluid was the very identical Æther or univerſal ætherial Medium ſo much inſiſted on by Sir Iſaac *Newton* and the learned Biſhop *Berkeley*; and though I had more than once taken notice of that portentous Paragraph with which Sir *Iſaac* concludes his Principia, and of his judicious Reaſoning thereon, whereby to account for the ſeeming active properties of inert matter, which appearances, he informs us, are the effects of the *Force and Action* of the ſubtile Fluid contain'd in its pores: Altho', I ſay, I

* See Princip. Lib. 3. Prop. 13. Where Sir *Iſaac* ſhews us how far we muſt proceed analytically, i. e. *a poſteriori*; and when we may ſafely proceed ſynthetically or *a priori*.

had

had taken ſome notice of theſe things before, yet I had not purſued the ſubject ſo far as to prove the exiſtence of that Fluid in the pores of groſs Bodies by ſuch convincing Experiments as are produced from Section 75 to Section 105, though almoſt every other Experiment in Electricity when examin'd will be found to confirm in ſome degree or other the ſame thing. This is ſo obvious, that none, who conſiders thoſe Experiments, can have the leaſt doubt of the truth of what I have advanc'd; and every true Philoſopher, i. e. every unprejudiced lover of Science, that has any regard either for the honour or memory of the illuſtrious Sir Iſaac *Newton*, will examine with due attention, the various Experiments, whereby the ſeveral operations of natural Cauſes and Effects may ſucceſſfully be traced and accounted for.

329. *Thirdly*. Another Reaſon which induced me to engage in this Subject was to ſettle that important Queſtion how a Fluid ſo ſurpriſingly elaſtic as the electrical Medium is found to be, can be retain'd within certain Limits in the open Air *, where, to appearance, there is nothing to prevent it from inſtantly eſcaping to regain an Equilibrium.

330. *Fourthly*. My chief Reaſon was to pave the way to the principal Thing I had in view, and which I have made the Subject of the ſecond Part of this Work, *viz*. A ſtrict Enquiry

* When accumulated on the prime Conductor, &c.

into the Nature and Properties of that abstruse Phænomenon FIRE: Being fully convinced that by means of the beams of Light reflected on it from electrical Experiments, *that* ambiguous and difficult Subject might be render'd much more clear and intelligible than it was ever capable of being made before.

331. Amongst my former Errors which (as hinted above) I intended to correct, the following was the greatest: In my first Essay and some part of my second (publish'd a few Years since) I, like every other Writer on Electricity, being much attached to the Term *Attraction*, made use of it on almost every occasion, without ever considering how unlikely it was that what was so exceedingly *elastic* and *impelling*, should at the same time attract, Attraction and Impulse being as destructive of each other as Light and Darkness; and a thing may as well be cold and hot, white and black, as at the same time attract and repel. So that I should have had nothing to keep me in countenance, had I not found the mistake so general, as that scarce any one Writer on the subject escap'd it.

332. I have before observ'd that Sir Isaac *Newton* when speaking of an æthereal Medium, describes it to be *much like Air in all Respects, but far more subtile.* In this light I have pursued my enquiries into the nature and properties of the subtile Medium so far as it is discoverable by the electrical Apparatus, and have always found it strictly to agree with Sir *Isaac's* definition

nition, and can therefore affirm that whoever examines the electrical Medium on the same Plan will not lose his labour, but will find the electrical Fluid, to be a most intelligible Thing*. For if truth may be collected from the greatest number of the clearest Experiments, and the most indubitable Facts, he who considers the Electricity, as it is called, as an universal pure Air, must be convinced of the truth of what I have asserted.

333. But as this universal Principle proves to be real Fire, it may perhaps be expected that I should enter on a particular explication of its Offspring Light, the true Essence of which we know but very little of, nor has the discovery of an universal Fire in Nature been as yet sufficiently cultivated to afford us proper requisites for our farther enquiries on Light with success; or indeed at all to enlarge our Ideas of it.——What however seems rational to conceive of it is, that so universal an Effect must derive its origin from as universal a Cause. Mr. *Chambers* and others, who have carefully collected the opinions of the best Authors extant in their time are somewhat obscure in their definitions of it.———Light according to Mr. *Chambers* is *that Sensation occasion'd in the Mind by the view of luminous Bodies; or that property in Bodies, whereby they are fitted to excite those Sensations in us.*' Other Expositors to the same Effect.

* And on any other Plan the most inexplicable.

The

The above named Author then proceeds to give a long detail of the Sentiments of others concerning it; but yet advances very little that is satisfactory and convincing besides what he has collected from Sir Isaac *Newton*'s Writings. From the foregoing Observations we also learn that the universal Fire or Æther in the pores of Bodies, when in its natural state, and before it is disturbed by our Experiments, is invisible. —— In this quiescent and latent state, the Ancients term'd it the *Substance of Light*, and Bishop *Berkeley* himself adopted the same Term *. Bodies are so variously temper'd that the universal Fire in their pores is very differently modified: Many appear luminous, when rubb'd in the open Air, and others will not emit Light but in vacuo, of which Mr. *Haukesbee* gives us a variety of instances; he shews that most Bodies exhibited a Light when Attrition was given to them in vacuo, flint and steel against each other excepted; even a mutual Attrition of two pieces of coarse woollen Cloth produced the same Effect. See Mr. *Haukesbee*'s Experiments, p. 35. — Many hard Bodies, such as Amber, Glass, &c. are remarkable for exhibiting Light in the open Air when rubb'd in the dark, but none so much as the Diamond. 'A 'Diamond on an easy, slight Friction in the 'dark with any soft animal substance, as the 'finger, woollen, silk, or the like, appears lu-

* Siris. 169.

'minous

'minous in its whole Body: Nay, if you keep 'rubbing for ſome time, and then expoſe it to 'the Eye, it will remain ſo for ſome time.' See *Chambers'* Encyclopœdia under the Word Diamond.

334. But if, excluſive of our phyſico-mechanical Experiments, we do but caſt our Eyes around and reflect on the Objects that preſent themſelves to us, we may ſoon be furniſh'd with a variety of others from Nature itſelf; ſuch Obſervations, or Experiments, if I may call them ſo, as are truly *phyſical*, as they are term'd, the Effect of which, i. e. the Light exhibited, is apparently deriv'd from the ſame Source, as that which we behold at the electrical Apparatus, namely, the pure Fire contain'd in the pores of groſs Bodies.——I ſhall inſtance in a few of both kinds which illuſtrate the Doctrine of an univerſal Fire.—If, for inſtance, a round ſmooth ſtick of Wood be well dried in an Oven, and then rubb'd with the hand, a flaſhing Light appears to follow the hand, if the Room be darken'd *.——Rub but the hairs of a Cat or a Horſe and preſently Fire or its Offſpring appears.———Shake but the Quickſilver in a Barometer or rub the upper end of the Tube briſkly between the thumb and finger, and a flaſhing Light appears in the vacuum.— Bodies in a periſhing ſtate, particularly thoſe which make the ſwifteſt tranſition from a ſound to a

* Experiment with the Mopſtick. *Section*, 209.

putrid

The Second PART.

CHAP. I.

Æther *confidered as* elementary Fire, *and* its Nature *under that Denomination* inveftigated.

I N the preceding Part I have confider'd the electrical Medium chiefly as a fubtile elaftic Fluid, and, in its natural State, invifible; yet it may be render'd an Object of our Sight by means of the electrical Apparatus, where it appears under the form of real Fire, *viz.* not only luminous, but, as Dr. *Franklin* hath by judicious and well chofen Experiments clearly fhewn, endued with the moft diftinguifhing Criterion of Fire, even that of melting the hardeft Metals in an inftant. I fhall therefore here confider it under that Character, and fhall begin with a brief Definition of it, founded on its effential Properties as demonftrated by the foregoing Experiments.

A Definition of Fire.

2. Firft. Fire *is an* Element *in the ftricteft Senfe of the Word, and confequently a permanent Principle.*

 Secondly.

Secondly. *That it is in form of an exceeding fine Air or Æther, and is, by means of Electricity, discover'd to exist in the pores of all gross Bodies with which we are conversant.*

Thirdly. *True Fire subsists without a Pabulum, and consequently yields neither smoke, Ashes, or any other gross feculent Matter.*

Fourthly. *True Fire is either hot or cold* *, *according to the temperature of the Body in which it exists.*

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* Here I expect to meet with the same Fate which most others have done, who, with an honest opposition to rooted prejudices have dared to advance paradoxical Truths.

Amongst the various methods adopted by shallow Minds for the deciding of Controversies, there is none more frequently made use of by them, than what is commonly term'd the HORSE-LAUGH. This, like an impetuous Torrent, carries all before it; no Remonstrance of Reason, no strength of Argument can obtain the least hearing in the tumultuous Uproar; nor shall I at all wonder if I experience such Treatment my self from the unthinking and prepossess'd Multitude, in whose injudicious and unphilosophical Ears *cold Fire* may sound as the highest Absurdity, a contradiction in very Terms. But the approbation of such incompetent Judges is what I am not so ambitious of as to offer an oblation, costly as Truth, at the Altars which their Fancies have erected. To my inquisitive, discerning, and unbiass'd Readers I address my Disquisitions on this intricate Subject, well knowing that they will examine with Temper, and decree with Justice.

3.

3. The Author thought a positive Definition of true Fire to be necessary, since elementary Fire is a Term frequently met with, but yet not always understood even by those who use it, and is therefore often taken in a vague sense, and in different meanings: I have therefore confin'd it to that particular and restrain'd sense which only it properly bears; no Fire having a right to the epithet pure, but that which subsists without a Pabulum and yields neither smoke nor Ashes; nor did we know of any that had the least pretension to such purity besides the solar, till we were agreeably surprised by the discovery of the electrical Fire.

A Definition of Heat.

4. Heat *is an accidental Property or Quality of Fire, generated at pleasure by the mutual Attrition of the Particles of the Fire: Or in other words, when Heat is produced by the Attrition of two Bodies, the strict and proper Cause of such Heat is the mutual Attrition of the Particles of the Fire contain'd in those Bodies.*

Illustration.

5. Hence Heat is generated, increased, and continued in proportion to the violence and continuance of the mutual Attrition of the particles of the Fire; and we shall have sufficient reason to believe (when we come to shew the method by which the greatest Heat was produced that was ever known*) that if it were

* That produced by *Villette*'s Mirrour.

possible

possible to divest any two Bodies of the Fire contain'd in their pores or interstices, no Heat at all would be produced by the Friction, tho' ever so violently, and ever so long continued.

6. Hence also, tho' the vulgar Expression, *Hot as Fire*, implies that heat is the very essence of it, yet, if we do but look back and reflect on the effects of the foregoing Experiments, we shall behold a cloud of Witnesses, all of them ready to testify, that heat is not an essential property of Fire, for Fire is not always hot, even when capable of melting metals, if effected by Electricity.——Dr. *Franklin* melted brass Pins and steel Needles, Gold and Glass: 'And tho'' says he 'I have taken up the pieces 'of Glass between my fingers immediately after this melting, I never could perceive the 'least warmth in them.' Dr. *Franklin*'s Letters, p. 66.

7. Again, tho' Water is naturally cold, yet we find the pores of nothing more plentifully stored with Fire than those of Water, nor is there any one thing besides metals, from which pure Fire can be so plentifully obtain'd: Since then, it always subsists in Water while in a fluid form, who can doubt the truth of the Assertion of that great Experimentalist Dr. *Boerhaave*, *viz.* 'that an incredible quantity of Fire is con'tain'd in the coldest masses of Ice, and may 'be instantly produced from them with a great 'deal of violence *?'

* *Boerhaave*'s Elements of Chymistry, p. 81, *Dallowe*'s Translation.

8. The ingenious *American* ſo frequently mentioned made more Experiments with this ſubtile Medium, and diſcover'd more of its properties as Fire, than ever was known to be done before by any one in Europe.——He informs us that he had five large glaſs Jarrs, which held eight or nine gallons a piece, each of which required a thouſand turns of a Globe nine Inches in diameter to charge it; but, ſaith he, 'I can 'charge and diſcharge them all together, as one. 'With the Fire obtain'd by this method, I have 'melted braſs Pins, and ſteel Needles, inverted 'the Poles of the magnetic Needle, given a 'magnetiſm and polarity to Needles that had 'none before, and inverted the Poles at plea-'ſure*, fired dry Gunpowder, *&c.* Two of 'theſe Jarrs, when charged, are ſufficient for 'theſe purpoſes.——Sometimes the Needles 'are finely blued like a Watch-ſpring; at other 'times melted.' He informs his Friend Mr. *Collinſon*, that he had ſent him ſome, with their heads and points melted off by his mimic Lightning; and a Pin, with its point melted off, and ſome part of its head and neck run. Sometimes the ſurface on the body of the Needle is alſo run, and appears bliſter'd. 'I ſend you 'ſaith he, two ſpecimens of Tin-foil melted by 'the force of two Jarrs only. There are no bounds, '(but what expence and labour give,) to the

* Who then can reaſonably doubt whether the magnetic Virtue and the electric Virtue be from the ſame *Cauſe*, or not, i. e. the univerſal Æther or Fire?

'force,

'force, Man may raise and use in the electrical 'way, for Jarr may be added to Jarr in infini-'tum, and all united and discharged together, 'the force and effect proportion'd to their num-'ber and size; the greatest known effects of 'common Lightning, may, I think, without 'much difficulty, be exceeded in this way, 'which may seem to many, a little too extra-'vagant to be credited †.'

9. At p. 64. of his Letters, he informs us, that 'Reading the ingenious Dr. *Miles's* ac-'count of the Thunder storm at *Stretham*, 'concerning the effect of the Lightning in 'stripping off all the paint that had cover'd a 'gilt moulding of a pannel of wainscot with-'out hurting the rest of the paint; I had a 'mind,' saith he, 'to lay a coat of paint over 'the filletting of gold on the cover of a Book, 'and try the effect of a strong electrical flash 'sent thro' that gold from a charg'd sheet of 'glass. But having no paint at hand, I pasted 'a narrow strip of Paper over it; and when dry 'sent the flash through the gilding; by which 'the Paper was torn off from end to end, with 'such force, that it was broke in several places, 'and in others brought away part of the grain 'of the Turkey-leather in which it was bound; 'and convinced me, that had it been painted, 'the paint would have been stript off in the 'same manner with that on the wainscot at '*Stretham*.'

* See Dr. *Franklin's* Letters on Electricity from p. 91. to 94.

10. ‘ Lightning melts metals, and I hinted ‘ in my Paper on that ſubject, that I ſuſpected ‘ it to be a cold fuſion ; I do not mean a fuſion ‘ by force of Cold, but a fuſion without Heat. ‘ *We* have alſo melted Gold, Silver, and Cop- ‘ per, in ſmall quantities, by the electrical flaſh. ‘ The manner is this : Take Leaf-gold, Leaf- ‘ ſilver, or Leaf-gilt-copper, commonly called ‘ Leaf-braſs, or *Dutch*-gold ; cut off from the ‘ Leaf, long narrow ſtrips the breadth of a ‘ ſtraw : Place one of theſe ſtrips between two ‘ ſtrips of ſmooth glaſs that are about the width ‘ of your finger : If one ſtrip of Gold, the ‘ length of the Leaf, be not long enough for ‘ the Glaſs, add another to the end of it, ſo ‘ that you may have a little part hanging out ‘ looſe, at each end of the Glaſs. Bind the ‘ pieces of Glaſs together from end to end with ‘ ſtrong ſilk Thread ; then place it ſo as to be ‘ part of an electrical Circle (the ends of Gold ‘ hanging out, being of uſe to join with the ‘ other parts of the Circle) and ſend the flaſh ‘ thro' it, from a large electrified Jarr or ſheet ‘ of Glaſs. Then if your ſtrips of Glaſs remain ‘ whole, you will ſee that the Gold is miſſing ‘ in ſeveral places, and inſtead of it, a metallic ‘ ſtain on both the Glaſſes ; the ſtains on the ‘ upper and under Glaſs exactly ſimilar in the ‘ minuteſt ſtroke, as may be ſeen by holding ‘ them to the light ; the metal appear'd to ‘ have been not only melted, but even vitrified, ‘ or otherwiſe ſo driven into the pores of the

'Glaſs, as to be protected by it from the action
'of the ſtrongeſt *Aquæ fortis* and *Aquæ Regia*.
'I ſend you incloſed two little pieces of Glaſs,
'with theſe metallic ſtains upon them, which
'cannot be removed without taking part of the
'Glaſs with them. Sometimes the Glaſs breaks
'to pieces; once the upper Glaſs broke into a
'thouſand pieces, looking like coarſe Salt.
'Theſe pieces I ſend you were ſtain'd with
'*Dutch*-gold. True Gold makes a darker ſtain,
'ſomewhat reddiſh; Silver, a greeniſh ſtain.
'We once took two pieces of thick Looking-
'glaſs, as broad as a Gunter's Scale, and 6 Inches
'long; and placing Leaf-gold between them,
'put them betwixt two ſmoothly planed pieces
'of Wood, and fix'd them tight in a Book-
'binder's ſmall Preſs; yet though they were ſo
'cloſely confin'd, the force of the electrical
'ſhock ſhiver'd the Glaſs into many pieces.
'The Gold was melted and ſtain'd into the
'Glaſs as uſual. The circumſtances of the
'breaking of the Glaſs differ much in making
'the Experiment, and ſometimes it does not
'break at all: But this is conſtant, that the
'ſtains in the upper and under pieces are exact
'counterparts of each other. And tho' I have
'taken up the pieces of Glaſs between my fin-
'gers immediately after this melting, I never
'could perceive the leaſt warmth in them.'
How vaſtly different this from our former con-
ceptions of Fire!

11. And now is it not ſurpriſing, that after
ſuch

ſuch powerful effects of the electrical fluid have been exhibited, any candid and unprejudiced Enquirer after Truth ſhould ſtill doubt, whether it be Fire or not? but ſtrange as it may ſeem, there are ſtill thoſe who not only barely deny it, but take no ſmall pains to prove the contrary: Among which, Meſſrs. *Hoadly* and *Wilſon* deſervedly merit the firſt place, ſince they affirm it to be as improper to call this Fluid by the name of Fire, as it would be to call Air by the name of Sound; which they attempt to prove thus,

12. 'When Sound is produced, the particles of the Air are put into ſo regular a motion, as to convey ſuch ſenſations by means of the Ear, as raiſe the Idea of Sound. But Air is not therefore Sound. In the ſame manner, when a Body has all its component particles thrown into ſuch agitations in the Air, by the force and action of this fluid within it and without it, that it grows hot and ſhines, and glows and conſumes away in ſmoak and flame, we ſay the Body is on Fire, or burns; but this Fluid is not therefore *Fire*: Nor can it without confounding our Ideas, have that name given to it; nor indeed can *Fire* be called a *Principle* or *Element* in the Chemiſt's ſenſe of the word, any more than *Sound* can.' —— See Obſervations on a Series of electrical Experiments by Dr. *Hoadly* and Mr. *Wilſon* p. 69. 70.

13. The forementioned Mr. *Jones* in his

'now to affirm, that these two fluids are one 'and the same fluid; as it is much more Philosophical to do so, than to suppose two such 'fluids, each of them equally capable of producing these effects, and equally present every 'where; which would be multiplying Causes, 'where there is no manner of occasion.'

25. Were we not too thoroughly convinced of the enslaving power of Prejudice, even sometimes upon Minds of a very ingenious cast, we might stand astonished at the foregoing instance of it in Messrs. *Hoadly* and *Wilson*. Who, after perusing the former part of their Essay, and finding how fully they had proved the electrical fluid to be the very identical Æther of Sir Isaac *Newton*, could imagine, that they should in the very same Treatise labour to persuade the World that this Æther was not Fire, notwithstanding it manifestly appeared to be possess'd of all the force and every essential property belonging to true Fire?

26. I am really sorry to find that even the Evidence of our Senses is not always convincing, and am loth to impute to any Person, in this enlighten'd age, a Conduct so illiberal and absurd as that which Mr. *Jones* pleasantly relates 'of a certain bigotted Philosopher at *Florence*, 'whose Prejudices had taken so deep root, that 'he could never be persuaded to look thro' one 'of *Galilæo*'s Telescopes, lest he should see 'something in the Heavens that might disturb 'him in his Belief of *Aristotle*'s Philosophy.' Mr. *Jones*' Treatise p. 191.

CHAP.

SECTION. 27.

Account of Fire *continued :* Pain *physically described.*

AMONG all the Enquiries I have been able to make into the Works of others, who have left us their thoughts concerning the nature and qualities of Fire, I could find ſcarce any thing that appear'd ſatisfactory, when compar'd with the Fire we have diſcover'd by means of the glaſs Tube and Sphere, beſides what Biſhop *Berkeley* has given us, who had adopted and improv'd the opinions of ſome of the Ancients concerning that difficult Subject. Almoſt all other modern Writers on Fire were for the moſt part dark and obſcure, and many times inconſiſtent with themſelves.

28. As I had not the Opportunity of peruſing a great number of Authors, my common method when I wanted to be inform'd concerning the popular opinion was to conſult my Oarcle, *viz.* that brief expoſitor Mr. *Chambers*, who appears to have taken great pains in collecting the Opinions of others. I hope to be excuſed for this, ſince, in that miſcellaneous Author, I could for the moſt part be well furniſhed, and generally from ſome of the beſt Authorities,

29. That brief Commentator informs us, 'That the most universal and sensible Character of Fire, and that which best defines it and 'distinguishes it from every other thing is its 'heating.—— Fire therefore may be defin'd to 'be whatever warms or heats Bodies.'

He then proceeds to give a more brief Definition of Fire and Heat, both of which are comprehended in his next four Lines.

30. '*Heat* is something whose presence we 'best perceive by the dilatation of the Air or 'Spirit in the Thermometer.——*Fire* may be 'defin'd to be that, whose presence we perceive by the expansion of the Air or Spirit in 'the Thermometer.' So that the candid Reader is to remember, that according to the common and receiv'd opinion, heat and fire were identically the same, the same definition being common to both. This therefore, to prevent any future dispute will, I hope, be carefully attended to; since denying the fact, can now be of no signification.—— The same Author informs us, that,

31. ''Tis a dispute of some standing among 'Philosophers, whether fire be any specific 'substance originally, distinct from all other; or 'whether it be the matter of other Bodies only 'under certain peculiar modifications, i. e. 'whether Fire be such by its own nature or 'by motion.'——The excellent *Boerhaave*, he tells us, has done wonders in his explanation of Fire.

32. But however, I shall not confine myself to Mr. *Chambers'* Account, but shall mention two of the greatest Authors, that ever adorned the English Nation, or probably any other, giving their Opinion on the same Subject, namely, the most renown'd Lord *Verulam*, and Sir Isaac *Newton*.

33. Mr. *Shaw* in his chymical Lectures, 2d. Edit. p. 26. when reasoning on Fire has the following quotation from the philosophical Works of Lord *Bacon* on that Subject, which is as follows:

34. 'If this method of exclusion and rejec-'tion were pursued to its due length, we should 'perhaps find no Criterion, infallible mark, or 'Characteristic of *Fire* in the general, but that 'of a particular *motion*, struggling among the 'small parts of Bodies, and tending to throw 'them off at the surface. If this should prove 'the case, then such a motion will be the form 'or essence of Fire, which being present, makes 'Fire also present, and when absent, makes 'Fire also absent; whence to produce Fire and 'to produce this motion in Bodies will be the 'self same thing.'

35. 'Sir Isaac *Newton* asks, *whether a Body* '*when it was heated hot, was not Fire; for* '*what else*, he says, *is a red hot Iron than Fire?*' —— 'Tis true, these opinions of those great Men appear to be but conjectures, but it seems they were the best they had to offer.

36. In the cultivation of natural Philosophy,

almost every branch of it besides that of Fire, has by means of Experience and Industry been more or less improved. This is so obvious as to be allow'd, I presume, by all. But that untractable Being, *Fire*, (if I may be allow'd the Expression) has baffled almost every attempt that hath hitherto been made to clear it up.

37. What can be the reason that such unsurmountable difficulties appear in almost every part of what we seem to be most intimately acquainted with, and what we number among even the common necessaries of Life? There being scarce any one thing in nature about which Mankind has been so much divided: —— Many of the Ancients, finding it to be most powerful in its nature, and universally extensive in its effects, worshipped it as the supreme Deity; and yet the very existence of it, as a permanent Principle, is denied by many Moderns.

38. In order to go to the bottom, so as to reconcile such differences, and point out their cause, it seems necessary to have so much recourse to Analogy, as to enquire and strictly examine into what has ever been the occasion of the greatest difficulties in the cultivation of other subjects; and then we shall soon find that they proceeded from mistakes and errors in the *First Principles*, which afterwards, on mature consideration, appear'd to be diametrically opposite to Truth. That we are too much inclin'd to judge of Objects from the appearances of Sense, rather than

the deductions of Reafon, the once receiv'd *Ptolemaic* Aftronomy may fuffice to fhew.

39. The Earth, according to that Syftem, 'tis well known, was placed in the center of it, with all the heavenly Bodies revolving about it in 24 Hours, altho' the greateft end that could be propofed to be ferved by it, was only to caufe Day and Night upon the Earth: That immenfe Body the Sun, by being at fo great a diftance, muft, to accomplifh his Circuit in 24 Hours, move at the rate of 176715 Miles every Minute, and the fixed Stars an indefinite number of times fwifter.

40. But fuch an amazing whirl of every one of the heavenly Bodies without exception was not the greateft difficulty of all: The Planets which in general were found to perform another motion round the Heavens the contrary way, in a particular number of days, inftead of moving regularly forward in their feveral Orbits as was expected, each one at a certain time, firft flacken'd its pace by degrees, till it quite ftopp'd, then ran back, then ftopp'd again, and after that went forward.—— Thofe Stations and Retrogradations of the Planets, were fuch Paradoxes as to be no ways accounted for, or folved, in a natural way: For which reafon Epicycles were invented to folve the feveral Phænomena.—— Had thofe Aftronomers confider'd the frugality of Nature, the concifenefs, and fimplicity obferved in all her Operations, that alone would have been fufficient to prove

the

the absurdity of the Plan, and that the whole was absolutely false.

41. But afterwards, when *Copernicus* revived the ancient System of *Pythagoras*, who had placed the Sun in the Center instead of the Earth, all those difficulties vanish'd at once, and an easy rotation of the Earth on its Axis in 24 Hours, was found sufficient to answer all that incredible celerity of the Sun, *&c.* in the *Ptolemaic* System.

42. Had there not been something of this kind, i. e. capital Mistakes in the first Principles, and from thence erroneous Conclusions drawn and taken for granted before they had been sufficiently examin'd, it would have been next to impossible to meet with so many ambiguities in any Subject we are so intimately acquainted with, as we are with Fire.

43. To prove whether this be the case or not, let us examine more particularly into the validity of those Principles which have hitherto been laid down and receiv'd, with regard to the nature of Fire: As, for instance, *That Fire has no Existence, as a permanent Principle.* What we call by that name, being nothing else than the particles of gross Bodies violently agitated by an intestine motion of the parts of those gross *Bodies*, and by that means violently thrown off at the surface and converted into Fire.

44. But nothing it seems could appear much more absurd and ridiculous to Professor *Boerhaave* than to suppose that the particles of gross

inert

inert matter were capable of being metamorphosed (whenever we pleased) into so active a substance as that of Fire. This is evident from p. 234. of his elements of Chymistry; where he reasons thus:

45. ' Tho' this elementary Fire induces an ' infinite number of changes upon all other Bo' dies, yet it never has appear'd by any Experi' ments, that any of them have ever been con' verted by it into true elementary Fire. And ' hence, it is not confirmed by any Observation, ' that Fire is able to multiply itself, by chang' ing its own Pabulum, or any Bodies into true ' Fire, by assimilating them to its own Na' ture; certainly, the more carefully we con' sider all the Effects of true Fire, the less ' conclusive those arguments appear, which ' are brought to prove such a power in Fire, ' or such an aptitude in other Bodies to this ' transformation. Hence therefore it evident' ly follows, that if Fire itself cannot from any ' other matter generate Fire, it cannot possibly ' be generated by any other matter. For what ' cause can by any action, produce Fire from a ' Body that is not Fire, if this cannot be effected ' by Fire itself? In the whole compass of Na' ture, certainly we discover nothing, that with ' regard to such a power, can any ways be com' pared with it. This seems to be the grand ' universal mover, from which every thing else ' receives its motion, all fluids at least, and per' haps a great number of solids; which is it-

' self

'self never begotten *de novo*, renewed or re-'suscitated, but is only rendered discernible, 'where it did not appear before.'

46. That I might be sure not to misrepresent the matter, so as to wrest the true meaning of the term; I consulted the common Expositors, such as Dictionaries, in which I found no material difference as to their several definitions, and any one who will but take the trouble of examining them, will find the language in general to be similar to the following.

47. *In* one.—FIRE *is the effect of a rapid internal motion of the particles of* BODIES.—In another, *the effect of a violent or rapid motion excited in* BODIES.—*In a* third *a violent rapid motion struggling among the small parts of* BODIES.

48. Another capital error is this. Modern philosophers had rejected and excluded a subtile ætherial medium out of their system. The very existence of such an universal Æther, as Sir *Isaac Newton* had pointed out, was denied; tho' in excluding it, they deprived themselves of an active agent; otherwise, this might have been the physical cause of such a violent rapid motion, as they affirmed absolutely necessary, to convert gross *Bodies* into *Fire*. Whereas, having deprived themselves of such an Aid, they had nothing to assign for the cause of that their supposed violent and rapid motion *struggling among the minute parts of Bodies, and tending to throw them off at the surface*; so that they seem

under

under a neceſſity of conſidering motion as a real Agent or Being; whereby it becomes both the *mover* and the *moved*, i. e. both Agent and Patient *.

49. Beſides, Fire and Heat were eſteemed one and the ſame thing; this was alſo taken for granted without any proof, conſequently it might be generated and deſtroyed at pleaſure; and a definition of Heat could vary but little from that of Fire. The following was the common language:

50. ' *Heat*, very much conſiſts in the ' rapidity of motion in the ſmaller parts of Bo-' dies, and that every way; or in the parts ' being rapidly agitated all ways.' [*Bailey.*] As this definition of Heat is general and much the ſame in all the reſt of thoſe brief Explainers of Terms, and ſo much like that of Fire, I ſhall trouble my reader with no more of them. —— Thoſe definitions by way of diſtinction, are ſaid by thoſe Expoſitors to be *according to the new Philoſophy.*

51. *Heat, Mr. Chambers ſays, is a particular idea or modification of our own Mind, and not any thing exiſting in that form in the Body that occaſions it. Heat is no more in the Fire that burns the finger, than pain is in the needle that pricks it.—In effect, Heat in the Body that gives it, is only motion; in the Mind, only a particular idea, or diſpoſition of the Soul.*

* See *Stephenſon* on Motion, Sect. 155. part 2d.

52. How rational ſuch a definition of Heat might appear, before Fire as a real Principle was diſcover'd to exiſt, and before it was known that Heat was a tranſient and variable quality of that Principle, and only exiſted in particular Circumſtances: How rational, I ſay, ſuch a definition of Heat might appear before theſe Diſcoveries were made, I cannot determine; but certain I am, that ſince ſuch Diſcovery, every part of the definition is found to be erroneous. —For tho' Heat be not eſſential to Fire, yet, whenever it is generated in any Body, how comes it to paſs that it is then, only a Senſation in the Mind of the Perſon that is burned by it? And is not the ſecond part of the definition as unintelligible, where he affirms that there is no more Heat exiſting in the Fire, even when hot enough to burn the finger, than there is Pain in the needle that pricks it? Whether this be not the greateſt abſurdity, and contrary to common Senſe and all Experience I may leave to the determination of almoſt every one. Again, how difficult is it to form any adequate idea of what he means, when he ſpeaks of that different ſenſation we experience between that of a burn and that of any other injury? Why the Pain of a burn in particular, ſhould be ſo widely different from other pains, I never experienced myſelf, nor have I met with any one that could, from his own knowledge, affirm ſuch a thing.

53. Pain tho' it may be diverſified in itſelf,

and may be different in degree, yet, as to its Eſſence and Cauſe, is ſtrictly and univerſally the ſame; that is, the Nerves and other Veſſels being ſo broken or otherwiſe wounded as to be render'd incapable of performing their proper Office; the free Circulation is thereby prevented, and Pain, or a diſagreeable Senſation immediately becomes the natural and neceſſary conſequence.

54. If this be ſo, and Pain or an uneaſy Senſation be felt whenever any parts are ſo wounded as to be render'd incapable of performing their Office, do not all Burns and Scalds cauſe Pain, and for the ſame reaſon that other Injuries do? Are not the Veſſels by being ſcorch'd and contracted, render'd as incapable of performing their proper function as if they had been wounded with a Pin, an Edge-tool, a ſtick, the laſh of a Whip, or with the Teeth of an Animal? But to proceed:

55. How vague, unintelligible, and unmeaning are his Sentiments deliver'd in the latter part of that definition, when he informs us, that *Heat, in the Body which gives it, is nothing but motion?* What is meant by *Motion?* What is it that is mov'd, and by what means? Can the definition be thought ſatisfactory ſo long as the meaning remains thus involv'd in obſcurity?

56. Other reaſons, beſides thoſe already enumerated, might be aſſign'd for the cauſe of the many Ambiguities relating to the Nature of Fire; but the principal one is, that before the

late great Discoveries made by Electricity, there was no proper foundation, no true Basis to found it upon: —— Before a more subtile elastic Medium than the common Air was found out, and that the same subtile Medium was real Fire, all that could possibly be said of it, was merely conjectural. For altho' divers of the Ancients, and some of the more discerning Moderns, had not only broach'd, but had very much cultivated the doctrine of an elementary, or universal Fire; yet, as there were not proper Experiments either to prove or countenance such a doctrine, the evidences produc'd, being thought not sufficiently clear, their doctrine of elementary Fire was rejected with contempt.

57. Many rejected an Æther, or a Medium more subtile than the common Air, as merely chymerical; Others, tho' they admitted of such a subtile Æther, yet, were so far from supposing it to be Fire, that they entirely rejected Fire as a permanent Principle, Agent, or real Being. Fire and Heat as before observ'd were esteem'd one and the same thing, and the Terms made use of synonimously; consequently with those, Fire might be generated and destroyed; Thus a subtile Medium being rejected by some, and Fire by others, difficulties inevitably ensued, and a doctrine contrary to both prevail'd.

CHAP.

CHAP. III. PART II.

SECTION 58.

The Opinion *of the* Ancients *concerning* Fire, *adopted by Bishop* Berkeley, *and confirmed by* Modern Experiments.

HAVING in the foregoing Chapter pointed out many palpable errors we had fallen into, when reasoning on the various qualities of Fire, and which were, for the most part, owing to the false conceptions previously form'd of it by us from early prejudices; it becomes more natural to remark, that so universal a Principle, as Fire appears to be, could not fail of exhibiting at all times its extensive Properties, and therefore happily long ago, some pursued their enquiries into the Essence of it, from its natural Effects. This appears to have been the case with respect to many of the Ancients, who, without the advantage of our modern Experiments on Fire, have given us a most accurate Account of it; an Account which corresponds and coincides with the Fire which we have found out by means of Electricity, to a most surprising exactness, as any one will see when he compares their Description of it with our Discoveries.

59. The learned Bishop of *Cloyne* afore-mention'd judiciously adopted their opinions, and collected most of them together in his SIRIS, where he has also given us many of his own Sentiments on the subject: I have subjoin'd the following extract from that curious Work, which will serve as an ample specimen for the present purpose, and, I shall hope, prove not a little entertaining to my Reader.

60. But before I enter upon my quotation from that great Author, I must observe that he receiv'd but little thanks from the World, during his whole life, for that valuable addition to the Libraries of the learned, for want of supporting his assertions with the Experiments that have been made in Electricity since his time; which have actually realiz'd every position of his, that fell within their reach, and may well put those to the blush, who were too much inclin'd to depreciate and condemn that most ingenious Production, and often contemptuously stiled it *a philosophical Romance*. — But the following extract from it will speak for itself, better than any thing I can advance in favour of it.

Bishop *Berkeley* on Fire.

61. 'The order and course of things, and 'the Experiments we daily make, says that 'learned Prelate, shew there is a Mind that 'governs and actuates this mundane System, 'as the proper real Agent and Cause. And

'that

'that the inferiour instrumental Cause is pure 'Æther, Fire, or the substance of Light; which 'is applied and determined by an infinite Mind 'in the *Macrocosm* or Universe, with unlimited 'power, and according to stated rules; as it is 'in the *Microcosm*, with limited power and skill 'by the human Mind.' Siris, *Sect.* 154. *&c.*

62. 'The Calidum innatum, the vital flame, 'or animal Spirit in Man, is the supposed cause 'of all motions in the several parts of his Body, 'whether voluntary or natural; that is, it is 'the instrument, by means whereof the Mind 'exerts and manifests herself in the motions 'of the Body. In the same Sense may not Fire 'be said to have force, to operate, and agitate 'the whole system of the World, which is 'held together, and informed by one presiding 'Mind, and animated throughout, by one and 'the same fiery substance?' § 156.

63. 'This pure Spirit or invisible Fire is ever 'ready to exert and shew itself in its Effects; 'Cherishing, Heating, Fermenting, Dissolving, 'Shining and Operating in various manners, 'where a Subject offers, to employ or deter'mine its Force. It is present in all parts of 'the Earth and Firmament, tho' perhaps la'tent, and unobserv'd, till some accident pro'duceth it into act, and renders it visible in its 'effects.' § 157.

64. 'There is no Effect in Nature, great, 'marvellous, or terrible, but proceeds from 'Fire; that diffused and active Principle, which

'at

'at the ſame time that it ſhakes the Earth and
'Heavens, will enter, divide, and diſſolve the
'ſmalleſt, cloſeſt, and moſt compacted Bodies.
'In remote cavities of the Earth it remains
'quiet, till perhaps an accidental ſpark from
'the colliſion of one ſtone againſt another,
'kindles an exhalation, that gives Birth to an
'Earthquake, or Tempeſt, which ſplits Moun-
'tains, or overturns Cities. This ſame Fire
'ſtands unſeen in the focus of a Burning-glaſs,
'till Subjects for it to act upon, come in its
'way, when it is found to melt, calcine, or
'vitrify the hardeſt Bodies.' § 158.

65. 'No Eye could ever hitherto diſcern,
'and no Senſe perceive the animal Spirit in a
'human Body, otherwiſe than from its effects.
'The ſame may be ſaid of pure Fire, or the
'Spirit of the Univerſe, which is perceived only
'by means of ſome other Bodies, on which it
'operates, or with which it is joined.' § 159.

66. 'In the human Body, the Mind orders
'and moves the Limbs: But the animal Spirit
'is ſuppoſed the immediate phyſical cauſe of
'their motion. So likewiſe in the mundane
'Syſtem, a Mind preſides, but the immediate,
'mechanical or inſtrumental Cauſe, that moves,
'or animates all its parts, is the pure elemen-
'tary Fire or Spirit of the World. The more
'fine and ſubtile part or Spirit is ſuppoſed to
'receive the impreſſions from the firſt mover,
'and communicate them to the groſſer ſenſi-
'ble parts of this World.' § 161.

67.

67. 'As the Soul acts immediately on pure 'Fire, so pure Fire operates immediately on 'Air; that is, the abrasions of all terrestrial 'things being render'd volatile and elastic by 'Fire, and at the same time lessening the vola-'tility and expansive Force of the Fire, whose 'Particles they attract and adhere to, there is 'produc'd a new Fluid, more volatile than 'Water and Earth, and more fixed than Fire. 'Therefore the Virtues and Operations im-'puted to Air, must be ultimately attributed to 'Fire, as that which imparts activity to Air it-'self *.' § 163.

68. 'The Platonists and Pythagoreans held 'Fire to be the immediate natural Agent, or 'animal Spirit, to cherish, to warm, to heat, 'to enlighten, to vegetate, to produce the di-'gestions, circulations, secretions, and organi-'cal motions in all living Bodies, vegetable, or 'animal, being Effects of that Element, which, 'as it actuates the *Macrocosm*, so it animates 'the *Microcosm*. ——— In the *Timæus* of '*Plato* he tells us, there is supposed something 'like rays of Fire: Doth not this seem to mean 'the animal Spirit, flowing, or rather darting 'through the Nerves?' § 166.

69. 'Æther by the ancient Philosophers 'was used to signify promiscuously sometimes 'Fire and sometimes Air. For they distinguish-'ed two sorts of Air. *Plato* in the *Timæus*

* See the 4th *Fundamental Principle*, p. 23.

'speaking of Air, saith, there are two kinds,
' the one more fine and subtile, called Æther;
' the other more gross and replete with Va-
' pours. This Æther or pure Medium, seems
' to have been the Air or Principle, from which
' all things according to *Anaximenes* derived
' their Birth, and into which they were back
' again resolved at their Death. *Hippocrates*,
' in his *Treatise*, *De diæta*, speaketh of a Fire,
' pure, and invisible; and this Fire, according
' to him, is that, which stirring and giving
' movement to all things, causes them to ap-
' pear, or, as he stiles it, come into evidence,
' that is, to exist every one in its time, and ac-
' cording to its destiny. § 168.

70. 'This pure Fire, Æther, or Substance
' of Light, was accounted in itself invisible and
' imperceptible to all our Senses, being per-
' ceived only by its effects.' § 169.

71. 'Such is the rarifying and expansive
' Force of this element, as to produce in an in-
' stant of time the greatest and most stupendous
' Effects; a sufficient proof, not only of the
' power of Fire, but also of the Wisdom with
' which it is managed, and with-held from
' bursting forth every moment, to the utter
' ravage and destruction of all things. And it
' is very remarkable, that this same Element,
' so fierce and destructive, should yet be so vari-
' ously temper'd and applied, as to be withal
' the salutary warmth, the genial, cherishing,
' and vital Flame of all living creatures.' § 170.

72.

72. 'Thus *Hippocrates* in his *Treatise De diæta*, speaks of a strong but invisible Fire, 'that rules all things without Noise. Herein, saith he, resides Soul, Understanding, Prudence, Growth, Motion, Diminution, Change, 'Sleep and Waking. This is what governs 'all things, and is never in repose.' § 174.

73. '*Theophrastus* in his Book *de Igne*, distinguisheth between Fire and Heat. The 'first he considers as a Principle or Cause, not 'that which appeareth to Sense, as a passion or 'accident, existing in a subject, and which is 'in truth, the Effect of that unseen Principle. And it is remarkable, that he refers 'the treating of this invisible Fire or Heat to 'the investigation of the first Causes. Fire, 'the Principle is neither generated nor destroy'd, is every where and always present; 'while its Effects in different times, and places 'shew themselves more or less, and are very 'various; soft and cherishing, or violent and 'destructive, terrible or agreeable, conveying 'Good and Evil, Growth and Decay, Life 'and Death, throughout the mundane System.' § 176.

74. 'It is allow'd by all, that the *Greeks* 'deriv'd much of their Philosophy from the 'Eastern Nations. And *Heraclitus* is thought 'by some to have drawn his Principles from '*Orpheus*, as *Orpheus* did from the *Egyptians*; 'or, as others write, he had been an Auditor of '*Hippasus* a *Pythagorean*, who held the same

'Notion of Fire, and might have deriv'd it
'from *Egypt*, by his Master *Pythagoras*, who
'had travelled into *Egypt*, and been instructed
'by the *Sages* of that Nation. One of whose
'Tenets was, that Fire was the Principle of all
'Action; which is agreeable to the Doctrine
'of the Stoics, that the whole of things is
'administred by a fiery intellectual Spirit. In
'the *Asclepian* Dialogue, we find this Notion,
'that all parts of the World vegetate by a
'fine subtile Æther, which acts as an Engine
'or Instrument, subject to the Will of the su-
'preme God.' § 177.

75. 'The Light, Fire, or celestial Æther,
'being parted by refracting, or reflecting Bo-
'dies, produceth variety of Colours; even so,
'that same apparently uniform Substance being
'parted and secreted by the attracting and re-
'pelling Powers of the divers secretory ducts
'of Plants and Animals, that is, by natural
'Chemistry, produceth, or imparteth the va-
'rious specific properties of natural Bodies.—
'Whence the tastes and odours, and medicinal
'Virtues so various in Vegetables.' § 181.

76. '*Boerhaave*, *Niewenty't*, and divers
'other Moderns, distinguish a pure, elemen-
'tary, and invisible Fire, from the culinary,
'or that which appears in ignited Bodies.
'This last, they will not allow to be pure Fire.
'The pure Fire is to be discerned by its Effects
'alone; such as Heat, dilatation of all solid
'Bodies, and rarefaction of Fluids, the segre-

'gating

'gating heterogeneous Bodies, and congrega-
'ting those that are homogeneous. That
'therefore which ſmokes and flames is not
'pure Fire, but that which is collected in
'the focus of a Mirror or burning-Glaſs.
'This Fire ſeems the ſource of all the Opera-
'tions in Nature; Without it nothing either
'vegetates, or putrifies, lives, or moves, or
'ferments, is diſſolved, or compounded, or
'alter'd, throughout this whole natural World
'in which we ſubſiſt; were it not for this, the
'whole would be one great ſtupid inanimate
'Maſs. But this active Element is ſuppoſed
'to be every where, and always preſent, im-
'parting different degrees of Life, Heat, and
'Motion, to the various Animals, Vegetables,
'and other natural productions, as well as to
'the Elements themſelves, wherein they are
'produced and nouriſhed.' § 190.

77. 'Pure Fire may be ſaid to animate Air,
'and Air other Things. Pure Fire is inviſi-
'ble; therefore Flame is not pure Fire. Air
'is neceſſary, both to Life and Flame. And it
'is found by Experiment, that Air loſeth in the
'Lungs the Power of feeding Flame. Hence
'it is concluded, that the ſame Thing in Air,
'contributes both to Life and Flame*. § 201.

* Almoſt every breath we reſpire, informs us that there is ſomething contained in Air, which is abſolutely neceſſary to Life: This is verified if the Bed-clothes are but wrapped and confined about the Head, ſo that no freſh Air may have room to

78.

78. Much more to the ſame Effect, is contain'd in his *Siris*, to ſtrengthen and confirm the doctrine of an univerſal Æther or Fire: But it is preſum'd, what I have tranſcrib'd is amply ſufficient for a Specimen. Thoſe, therefore, who are converſant with that Theory on Air, Æther, and Fire, may eaſily turn over ſuch of the Sections which may be thought ſuperfluous; while others, perhaps, who never ſaw it, will not be offended at their number.

79. Had it been the Biſhop's Lot, inſtead of Profeſſor *Muſſchenbroek's*, to have diſcover'd the famous Experiment with the Phial, ſince

paſs. For how ſoon after that, are we ſenſible of a pain in the Cheſt? which increaſes, in proportion to the number of Times the Air has been breathed.

Does it not from hence appear that the Air when in the Lungs, is diveſted of the ſalutary Particles, and the heterogeneous noxious Particles excluded at the next Expiration, and again repleniſh'd at the ſucceeding Inſpiration? Theſe are alternately performed with the greateſt facility, ſo long as we breathe in open Air. But the Caſe is quite otherwiſe when we attempt the above Experiment; for as ſoon as we have breathed the ſame Air a few times over, the Pain begins. The pent up Air having parted with more and more of its Fire after every Inſpiration, the Velocity of the Blood being thereby more retarded for want of a freſh Supply, the Pain increaſes, and as every one well knows, would in a little time, if the Experiment were continued, prove fatal.

call'd

call'd the *Leyden Experiment*? Had he been throughly acquainted with the subsequent Improvements which have been made in Electricity, and concealed the Discovery of them till he published his *Siris*, instead of the form in which it now appears, he might have concluded it after the following, or a similar Manner.

80. I am throughly convinced that had I published this Account of Æther or Fire, unsupported with Experiments, it would have been rejected as romantic; but I can with the greatest Pleasure and Satisfaction, inform my Readers, that I have happily discover'd the very ætherial Medium which I have here been treating of, and by means of a simple Machine and very little Labour, am enabled to produce it; not from the Air encompassing the Machine, as might be supposed, but from the Earth, Waters, Minerals, Animals, Vegetables, &c. And what will seem much more strange, I can not only demonstrate it to be Fire; but can collect the same Fire from the Thunder-clouds in great abundance; and retain it even in such plenty, as, when let loose, to produce loud claps of Thunder*; and what will undeniably prove it to be that very identical Fire which I collect at my Machine, I can make the very same Experiments with it; so that I am throughly convinced, that this wonderful Agent must be Universal, and that all Nature is re-

* See *Romas*'s *Kite*, Sect. 313. 314. Part I.

plete

plete with it. And, notwithstanding the extreme Elasticity and Subtilty with which it is endued, I can collect and retain it, in almost what quantity I please, whereby all its most essential and accidental Properties may be easily discover'd by proper Experiments.

81. Had the substance also of what is contained in the foregoing Sheets been introduc'd, with all the additions and graces with which so accomplished a Writer was capable of adorning the Subject, what a different Effect would it have had on the Minds of Men, who were all, till then, ignorant of the Existence of any such active mechanical Agent in Nature? What a general Reception would his Book have met with? Who, after that, would have doubted whether the electrical Fluid just then discover'd, (which was endued with the same Qualities that he had ascribed to his ætherial Fluid,) was the *same* Fluid or not, particularly, since it evidently appears to be actual Fire, insomuch as not only to kindle up combustibles into a real Flame, but to fuse Metals in an Instant*?

82. In a Word, this is the universal Subtile Æther so much like Air, which according to Sir *Isaac Newton*, is expanded throughout all the Heav'ns†, and the same which he affirms to lie hid in the pores of all gross Bodies‡; and this Æther is also the pure elementary Fire of

* As in Dr. *Franklin*'s *Experiments*. † *Optics*, Quære 18th. ‡ *Princip*. Lib. 3. p. 393.

the

the Ancients, which I have diſcover'd to be permanent.

83. So true it is, that an Object, firſt foretold and explain'd, and then view'd at once in its full extent, will ſtrike the Mind, and appear convincing, when the ſame thing ſeparately ſeen will not; eſpecially, if when we view it thus disjoined, and in ſo many broken points, we expect nothing very extraordinary, beyond what we ſee at each particular time, which has been the caſe with reſpect to the preſent Subject.

CHAP. IV. PART II.

SECTION 84.

Fire *not a Quality, but a created Entity, of a poſitive Nature and permanent Exiſtence.* — Heat *how produced.* — Vilett's Mirror, *its Conſtruction, and ſurprizing Effects.*

TO expect an Author to deſcant with Perſpicuity and Correctneſs on the various Phænomena of the Creation, whilſt he remains ignorant of the true Nature of Fire, that allowed Cauſe of all Motion, — ſeems to be as unreaſonable as the rigorous demand of the Egyptian Taſkmaſters, who re-

quired Brick to be made without allowing the neceſſary article of Straw.

85. What I would intimate by this Alluſion is, that before the Diſcoveries which Electricity has made, it was morally impoſſible we ſhould argue with any manner of clearneſs on Fire; ſince there did by no means appear ſufficient Evidence to convince us that Fire had any real Exiſtence amongſt created things, otherwiſe than as ſomething factitious, that might be generated and deſtroyed at pleaſure; generated by the attrition of any two hard Bodies againſt each other, and deſtroyed by Water. Little did we think of an actual Fire that ſubſiſted in thoſe Bodies; and that we could not rub any two Bodies together, but we muſt rub at the ſame time the inviſible Fire in the pores againſt each other, at the ſurfaces of thoſe two Bodies; and that the mutual attrition of the parts of the Fire was the true cauſe of the Heat: We could hardly perſuade ourſelves but that the Heat, which was by ſuch means generated, was Fire itſelf, and accordingly we called it by the ſame Name, and continue to do ſo to this Day.

86. In a Word, this is now grown ſo habitual, that nothing appears much harder than to diſſociate the two Ideas of Fire and Burning; whereas, if we do but conſider Experiments attentively, as I obſerved before, we cannot be much more certain of any one thing from thence, than, that Heat is no innate Qua-

lity;

lity; or, that Fire is naturally hot any more than other things. True indeed it is, a very inconſiderable degree of Attrition of its parts againſt each other will excite Heat. But on the other hand, if it happen to have a leſs degree of agitation than common, it is actually cold like other Bodies, and the forementioned Experiment of Profeſſor *Boerhaave*'s*, is an undeniable proof of the truth of it.

87. So long as we were ignorant of a permanent Fire, exiſting in Nature, all that could be ſaid of it ſeem'd like confuſed Conjecture.

88. The following Experiments will convince us how neceſſary the mutual attrition of the parts of Fire is, to generate or increaſe Heat, and that it does not abſolutely depend on adding a greater quantity of Fire together as is ſuppoſed.

To illuſtrate the foregoing Reaſoning.

89. It is preſumed it will be allowed, that the Fire in a red hot Iron juſt taken out of the *Smith*'s Forge-fire would receive no increaſe of real Fire by agitating the ignited Iron with cold Air, blown upon it; for this I believe no one can reaſonably ſuppoſe: But tho' more Fire cannot be added by this means, yet the Fire in the Iron may by ſuch means be ſo agitated, heated, and ſo expanded, as to ſeparate

* That an incredible quantity of Fire may be obtained from a maſs of Ice.

the parts of the Iron and occasion a fusion to ensue; I must own when I was first informed of the Effects of that Experiment, it appeared incredible, and I was determined to examine it by making the Trial; the effects of which were as follow:

90. A lump of Iron was made red hot, which being taken out of the Forge-fire, was laid on the Anvil and blowed with a pair of Kitchin Bellows, which, as I imagined was more likely to cool it; but I soon found myself mistaken, for instead of that, tho' the heat of the Forge-fire was not sufficient to melt the Iron, yet by agitating the Fire in the Iron, with the Fire in the Air from the Bellows, the Heat, was so increased and consequently the expansion of the Fire, that the particles of the Iron were separated and fused: At every fresh blast of Wind, particularly if violent, the Light was so intense as to dazzle the Eyes of those who looked stedfastly on it, like beholding the Face of the Sun. The stronger those Blasts were, the brighter was the Fire: Between each Blast, a Cloud as it were, instantly covered the Brightness; which Cloud was again dissipated by the next Blast of Wind. The stronger the Blast, as before observed, the brighter and paler was the Hue of the Fire, and the more the liquid Iron ran down *.

* Quære, Whether the effects of this Experiment do not indicate the vast, constant, and uniform

91. Something ſimilar to this may be effected by giving to the end of an Iron Rod, what is called a welding Heat, and then ſhaking, or whiſking it about very briſkly in the cold Air, for by this Operation, the heated part of the Bar will be fuſed likewiſe. And 'if a 'large ball of ſolid Iron is fired from one of the 'biggeſt ſort of Cannons in the Winter; tho' it 'will run thro' the cold Air 600 feet in a Se'cond of Time, (which is 27 $\frac{3}{11}$ times ſwifter 'than the ſtrongeſt Wind,) ſuch a Ball when it 'has run thro' its whole way, with that violent 'rapidity, and falls to the ground, is found per'fectly hot, altho' thro' its whole paſſage, it has 'been conſtantly expoſed to freſh cold Air. *' The ſame doctrine is illuſtrated by only hammering the end of a long cold Nail very briſkly on an Anvil; by which means the particles of Fire contained in the Iron will be ſo agitated againſt each other and become ſo hot, that the end of the Nail will very ſoon be red with the Heat of it. To prevent the metal from growing red hot and unfit for working, the Artificer, who bores the *Gun-barrels*, is obliged to make uſe of a ſtream of water, which conſtantly falls on the part which is agitated with the end of the Boring-tool. Many other inſtances might be enumerated to ſhew that

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Motion at the Sun; where an aſtoniſhing, regular brightneſs is perpetually exhibited?

* *Boerhaave's Chymiſtry.* p. 112.

when

when the Fire contained in groſs Bodies is by any means agitated, that then Heat commences.

92. If the Bodies rubbed together are a Pabulum of Fire, *viz.* any combuſtibles, as two dry Sticks, *&c.* then if the friction be continued with violence, the contained Fire grows ſo hot as to faſten on the Pabulum, and kindle it up into a flame, by which means, the agitation and heat of the Fire is ſtill increaſed, and continues till the combuſtible is conſumed.

93. That real Fire can be totally deſtitute of Heat, has been always thought ſuch a palpable Contradiction, that it was imagined no ſober Man, if he was in earneſt, would maintain ſuch a doctrine: But whether the electrical Matter be not true Fire; or whether Heat be an eſſential Property of *that*, it is preſumed, may be left to any ſober Man to determine, after he has ſeriouſly conſidered the Experiments. And not only electrical, but all other Fire, (if it can be thought reaſonable to ſuppoſe that there are different kinds of it,) if carefully examined, will appear when in its ordinary ſtate, to be deſtitute of Heat, even the pure ſolar Fire itſelf, tho' it is found capable of being rendered ſo hot as almoſt to exceed all human Credibility, as will evidently appear a little farther on.

94. That the ſolar Rays are naturally deſtitute of real Heat, we find verified by only conſidering, that ſo long as thoſe rays paſs on uniformly

formly by the ſide of each other in their rectilinear Motion, no effects of Heat appear, or even warmth, ſufficient to melt the Snow on the tops of high Mountains. Heat from the Sun ſeems the effect of agitated Rays, i. e. agitated by their mutual attrition againſt each other, or rather of their interſecting and actual croſſing of each other; and as this ſeems the abſolute cauſe of all ſolar Heat (as will very ſoon appear to be the caſe) I beg it may be carefully attended to. There are no denſe neighbouring Bodies at the tops of the higheſt Mountains to reflect, or otherwiſe turn thoſe rectilinear Rays out of their direction, but they fall immediately on the Snow, from which they are again ſo eaſily and ſo inſtantly reflected off, as never ſo much as to warm it. This is well known to be the caſe, even in Countries within, or near the torrid Zone itſelf, altho' the Meridian Beams of the Sun, at certain times, ſtrike almoſt, if not quite directly on it: But, as ſoon as thoſe parallel Rays, as they are called, are by any means, i. e. either by reflection or refraction turned out of their rectilinear direction, then, and not till then, they afford ſome degree of warmth. As to real Heat, it appears to depend altogether on the reflected Rays from the neighbouring Bodies around; for at the bottom of thoſe very Mountains, where the Sun's Rays are variouſly reflected, the moſt ſultry Heat is produced. It is alſo well known that the more ſmooth, denſe, and compacted

Bodies are, so much the stronger are the Rays reflected, and the heat proportionally increased. This being constantly and invariably the case, more examples would be unnecessary, were it not that such considerations, naturally conduct to those artificial contrivances of refracting and reflecting the Solar Rays out of their rectilinear course, i. e. those of burning Glasses and metalline Mirrors; which, by means of their bending the Rays in such a manner, that they all tend to one point, the attrition of the Rays, at that point (by means of the vast rapid motion, with which they are hurried forward) becomes so exceeding violent by intersecting or actual crossing, that those which fall on a glass Lens, of little more than half an Inch Diameter, will actually burn at the Focus, consequently if the Area of the glass Lens or Mirror be sufficiently enlarged and the number of Rays proportionably increased thereby at the Focus, where such a number of Rays do really intersect, the Heat becomes intense.

95. To confirm the foregoing Doctrine concerning the great efficacy of those Glasses to produce Heat by means of agitating the particles of Fire by their mutual attrition, I shall take the liberty of transcribing what I find in the Works of the ingenious and indefatigable Professor *Boerhaave*, concerning those solar Burners; or at least, so far as seems necessary for my present Purpose, and this I shall do for these Reasons. First, because I am not the most ready

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at Compoſition myſelf, and am therefore deſirous of enriching my Work with quotations from others, whenever they ſpeak my own Sentiments. And Secondly, becauſe he is an approved Author, and allowed by all to deliver his Sentiments with Propriety and Elegance. —— In Page 146. of his chymical Lectures, he informs his Pupils, that altho' the power of burning Glaſſes had been a long time diſcovered, 'yet it ' never appeared more accurately than by the ' Glaſſes of Mr. *Tſchirnhauſen* in the poſſeſſion ' of the Duke of *Orleans*, which were made ' uſe of in the Palace Garden, on purpoſe to ' try ſome Experiments concerning the Nature ' of Fire; the Effects produced by theſe Glaſ- ' ſes being the greateſt that were ever pro- ' duced by any of the ſame kind.'

96. 'The biggeſt Glaſs is of a circular Fi- ' gure, four Feet in Diameter, and convex on ' both ſides; it produces a Focus at 12 Feet ' diſtance from the Glaſs, whoſe Diameter is ' an Inch and half, this is what Mr. *Tſchirn-* ' *hauſen* made uſe of himſelf.'

97. 'If combuſtible Bodies are placed in ' this Focus, they take fire immediately; Lead ' is ſoon melted, and Bricks are vitrified, if ' they continue there a good while.'

98. 'The noble *Tſchirnhauſen* however, not ' being ſatisfied with the preceding Experi- ' ment, began to think of contracting the ' former Focus into a narrower compaſs, and ' by this cloſer union of the Rays rendering its

'cauſtic Power more intenſe. For this pur-'poſe therefore he made uſe of a ſmaller 'glaſs Lens, the ſegment of a leſſer Sphere, 'which, being placed directly parallel to the 'former, received all the Rays that were col-'lected by that larger one, and were proceed-'ing on to its Focus, and contracted them in-'to a circular ſpace of only eight lines dia-'meter, and conſequently, by this new con-'traction, reduced theſe Rays from an Area 'of 81 lines Square, to one of 16. But though 'by this method he brought them into a near-'er union, yet he loſt a great many Rays by 'this ſecond refraction; though this, however, 'did not hinder but that the cauſtic Power 'of this latter Focus, was ſtronger than the 'former. And this was the ultimate effect of 'the ſkill of the celebrated *Tſchirnhauſen*.'—*ibid.* 147.

99. But Philoſophers ſoon found, that if the back of a commong Speculum or Looking-Glaſs, inſtead of being flat, *be* ground convex, ſo as to be the ſegment of a Sphere, and an amalgamy laid on it in the manner the back of a common Looking-glaſs is quickſilver'd; then if ſuch a mirror be oppoſed to the Sun, the ſolar Rays falling on the poliſhed Metal, (which in this caſe is concave) will be *reflected* back again into a point, or Focus, where they will burn much more intenſely than if a Glaſs of the ſame Focus be made uſe of as a Lens for Burning, by *refracting* the Rays.

100.

100. It was farther obſerved, that if ſuch a catoptrical Inſtrument for Burning was made of poliſhed Metal inſtead of quickſilver'd Glaſs, the focal Heat was ſtill increaſed, probably, becauſe in the former caſe, the Rays paſs thro' the Glaſs before thay can be reflected back by the poliſhed ſurface, and repaſs thro' it before they arrive at the Focus. — The Heat however that has been generated, by means of a highly-poliſhed concave metalline Mirror, has been found ſo violent as almoſt to exceed all human Credibility.

101. ‘ Not to mention many others, it will ‘ be ſufficient to take notice of the moſt per‘ fect one hitherto known; and this is that, ‘ which, with a good deal of experience and ‘ labour, was made by thoſe excellent *Artiſts*, ‘ the Father and his two Sons, the *Vilett*'s of ‘ Lyons. This Mirror is formed of a metal‘ line ſubſtance, nicely compounded after a ‘ great many trials for this purpoſe, and is of ‘ a concave ſpherical Figure, the Chord of the ‘ Segment of the Circle, by the revolution of ‘ which it is conſtructed, or the Diameter of ‘ the Circle, which meaſures its Aperture, being ‘ 43 inches, and conſequently, the Area of the ‘ plane, through which the Rays are admitted, ‘ 1452 $\frac{11}{14}$ *French* Inches. Both the concave and ‘ convex ſides of it are ſpherical; and both Sur‘ faces are poliſhed as nicely as poſſible. The ‘ whole Maſs of the Speculum weighs 400 ‘ *French* pounds; and laſtly, the Rays, which

'fall upon the Speculum through the Aperture abovementioned, when it is directly opposed to the Sun, are collected in the Air, within a Circle of half an inch diameter, which is $3\frac{1}{2}$ feet distance from its vertex. Hence, therefore, if all the Rays that come parallel from the Sun, and are received by the Speculum, were reflected into this Focus, then the Space they took up in the Circle of the Aperture of the Speculum, would be to the Space into which they are thus contracted in the Focus, as 7396 is to 1; and consequently, there would be seven thousand three hundred ninety-six times more *Fire* in this Focus, than in the Air heated at the same time by the Sun; which is, certainly, a prodigious difference.'

102. 'Within the space of a Minute, the six Metals were put in fusion at the same Focus; as also, all the Semi-Metals that have hitherto been tried; even stony and rocky Bodies, are melted and vitrified by it in an instant: And how violent its effects must be, may be seen from this instance, even Bones themselves, whose Ashes we know, in the Cupelling Test, so powerfully resist both Fire and Lead, are melted by it in the twinkling of an eye; as are likewise Bricks, Clay, Sand, Crusibles, Marble, Jasper, and Porphyry, which are turned into Glass. And lastly, the very Stones which the Masons make use of for building the Furnaces designed for

'fusing

'fusing of Iron, and ſeparating it from its vaſt 'hard foſſil Ore, melt and vitrify in this Fo-'cus immediately; which no perſon, let him 'underſtand theſe things ever ſo well, or let 'him have ſeen ever ſo much of the violence 'of confined Fires, could ever have imagined; 'for theſe ſame Stones would have remained 'many Years without alteration, in the in-'tenſe Fire to which theſe Furnaces are always 'expoſed: So that the power of this focal 'Fire, is able to effect that in the leaſt inſtant 'of time, which the other, tho' the ſtrongeſt 'we know of beſides, could hardly accompliſh 'in the ſpace of ſome Years. And yet, this 'Fire reſides in the liquid Air, nay, perhaps, in 'vacuo, the Air being expelled by this vaſt 'Heat, and that without the leaſt Pabulum 'to ſupport it; and it always remains there, 'ſo long as the Solar Rays continue to fall 'upon the Speculum.' *Boerhaave*'s Chym. Vol. I. p. 134. *Dallowe*'s Tranſlation. —— See *Definition* of Heat, Part II. § 4.

103. I muſt acknowledge myſelf greatly indebted to that Author for this hiſtory of the Mirror; for altho' *Vilett* brought it to *England*, yet I never ſaw it ſo minutely deſcribed by any *Engliſh Writer*, and therefore muſt have been ſo far ignorant of ſuch a marvellous Power in the Solar Rays; but yet I hope to be excuſed tho' I ſhould differ from that celebrated Profeſſor in my Sentiments, concerning the manner that aſtoniſhing Heat is generated, eſpe-

cially

cially after I have given my Reaſons for ſo doing.

104. This renowned Author ſeems very careful to avoid any fundamental Errors, and particularly in his enquiry into the Nature of Fire; yet he (with many others) ſeems guilty of a material, tho' common miſtake: He takes it for granted, that the cauſe of the great Heat at the Focus of burning Glaſſes and Mirrors, is the cloſe union of the ſolar Rays at that point; whereas, were that the true Cauſe, there muſt neceſſarily be a gradual decreaſe of the Heat from the focal Point, quite down to the face of the Mirror, where the parallel Rays firſt begin to converge; i. e. at a quarter of the focal diſtance from the Mirror, there muſt be nearly a quarter of the Heat; at half the diſtance, half that Heat; at three quarters, three quarters of the Heat, *&c.*

105. It muſt alſo ſeem reaſonable to expect that ſo near the vertex of the Cone of reflected Rays, where the Focus of *Vilett*'s Mirror becomes of the ſame ſize with the focus of *Tſchirnhauſen*'s glaſs Lens, viz. of an inch and half Diameter, that it ſhould burn at the ſame part, proportionably with *Tſchirnhauſen*'s Glaſs; whereas, we do not hear of any conſiderable Heat any where but juſt in the focal point, conſequently the mere collecting of the Rays into a leſs ſpace cannot be the Reaſon of that intenſe Heat.

106. Is it not rational to ſuppoſe that the cauſe

caufe of fuch a furprizing Heat, at the very Focus only, is from the violent attrition which the Rays fuffer at that particular point, more than any where elfe, by means of their actual croffing each other at that part, particularly, fince the *natural* Heat of the Sun in other circumftances appears to be from the fame kind of attrition of the Rays againft each other, as was before obferved. — But when we confider fuch a number of Rays crowded into the compafs of a Circle of half an Inch Diameter*; while thofe Rays are allowed to be paffing on, with the velocity of ten millions of miles in a Minute, the effect, i. e. the Heat at the Focus, feems but the natural confequence of the Premifes, viz. the effect of the croffing of fuch a number of the Rays, at that point with fuch inconceivable Celerity. Nor does the reflection, or refilition of matter, fo perfectly elaftic as the folar Rays, againft the Speculum, feem to deftroy any part of the velocity of the Rays, fince the heat at the Focus is fo very intenfe after reflection. Does it then receive an additional Impetus at the face of the Speculum? Glafs Reflectors al- error fo burn more powerfully than glafs Refractors, though the Sun's Rays pafs twice through the Glafs in the former, and but once in the latter.

107. But tho' it be evident, that the Sun's Rays do really crofs each other at the Focus of a

* The Diameter of the Focus.

burning

burning Glaſs or Mirror, to all thoſe who are verſed in Optics, or who have made Experiments with a triangular glaſs Priſm in a darkened Room; yet for the ſake of thoſe who are ſtrangers to thoſe Helps, I ſhall take the liberty of delineating an Experiment to explain this Operation of Nature —— by which, all who pleaſe, may have ocular Demonſtration that the Sun's Rays interſect at the Focus of burning Glaſſes, *&c.*

Experiment.

108. Let S Plate 2d Fig. 6. repreſent the Sun. A B the Window ſhutter of a darken'd Room. C the Aperture thro' which the Sun's Rays are to paſs to the Priſm D E F; thoſe Rays, after paſſing thro' the Priſm, will begin to diverge. At a ſmall diſtance beyond the Priſm at G H, let a Sheet of white Paper be held, whereon the Rays may fall; which will appear red at the bottom, and of a violet colour at the Top. If the paper be removed to K and a convex glaſs Lens be held to ſupply its Place at G H, the painted Rays after paſſing thro' the Lens will converge and come to a Point or Focus at K, in like manner, as when the ſame Lens is uſed as a burning Glaſs, at which focal Point the Colours diſappear; and to prove that the Rays croſs at that Point, if the Paper be moved beyond the point, the Colours begin to appear again, but inverted; ſo that the red Rays, which before at H appeared at

bottom

bottom, do afterwards appear at M at the top; and the violet Rays, which before appeared at the top at G, do afterwards appear at the bottom at L. See Sir *Iſaac Newton*'s *Optics*, 3d. Edit. Book I. Part II. Experiment 10.

109. But excluſive of this Experiment, no one can reaſonably doubt of the Rays interſecting at the Focus of Burning-Glaſſes, who does but obſerve, that if a common Burning-glaſs be oppoſed to the Sun, and the Object, on which the refracted Rays fall, be held ſhort of the Focus, and moved gradually farther and farther from the Glaſs, that the lucid Circle grows leſs and leſs till the Object comes to the Focus, and after that, if it be moved ſtill farther and farther, the Spot enlarges in the ſame proportion as it leſſened before.

110. From the foregoing Account of *Vilett*'s curious Mirror, and a due conſideration of the ſimilarity of the electrical Fire and the elementary Fire of the Ancients as explained by Biſhop *Berkeley*, we might (were it not for prejudice) arrive at every thing neceſſary to conduct us to the Knowledge of the Nature of that abſtruſe ſubject FIRE. This being the Caſe,

111. I ſhall therefore once more enquire into the *original* Cauſe of all our miſtakes concerning Fire, becauſe, probably after that, we may ſo far prevail with ourſelves, as to examine the Evidences on the other ſide. — Such capital Miſtakes on Enquiry, we ſhall find to be entirely owing to the manner of receiving our

first Ideas, viz. by the Senſes.

112. Thoſe early Impreſſions that were made upon us by that *Element*, or Principle, were from its Effect; viz. the Heat we received from it. For which reaſon it was ſcarce poſſible for us to make a proper diſtinction between the Fire and the Heat; that is, between the *Cauſe and the Effect*. We imagined that Fire was Heat, and Heat was Fire; and even to this day we confound the Terms and uſe them promiſcuouſly, inſomuch, that whenever we found the greateſt Heat, we always thought it a ſure and certain Mark of the greateſt quantity of Fire; whereas, from the foregoing Reaſoning, it evidently appears that a greater Heat is only a ſign of a greater Attrition of the parts of Fire againſt each other.—— That common and predominant foible, which is ſo naturally interwoven as it were into our very *Make* and *Conſtitution*, namely, that of judging of things according to Senſe, prevents us from attempting a ſtrict examination: The firſt Impreſſions are generally ſo ſtrong and ſo deeply rooted as to be a kind of ſecond Nature, and which is ever improving through length of time; and ſince nothing can be of much longer date than ſuch Miſtakes concerning the Nature of Fire, it can be no wonder if they ſhould be found the moſt difficult to eradicate of any others.

113. Another capital Miſtake is our laying it down as a ſure Maxim, that the *motion* of Fire is the ſole cauſe of Heat. The Solar

Rays

Rays for inſtance, which all allow to be real Fire, the motion of which is ſo great as to move at the rate of ten Millions of Miles in a Minute, yet, they are not poſſeſſed of any Heat or warmth, ſo long as they paſs on uniformly by the ſide of each other. See Sect. 79. Part II. Nor is the cloſer union of the Rays of much greater effect, ſince no conſiderable Heat was produced in all the whole limits of the Cone of Rays of *Vilett*'s Mirror, but at the Vertex only; which, had the cloſer union been the Cauſe of the Heat, ſuch Heat muſt as obſerved at Sect. 107. Part II. have been gradual, and in proportion to the diſtance fiom the Focus. Conſequently the intenſe Heat was, as before obſerved, the Effect of the violent Attrition that the Rays muſt neceſſarily ſuffer at the place of Interſection. Can it appear ſtrange then, if amidſt ſo much Ignorance and ſo many formidable Errors the Subject ſhould ſeem untractable, as it is called? Aſtronomy and other Sciences were neceſſarily as untractable and unſatiſfactory ſo long as we endeavour'd to account for Appearances from falſe Principles. See Sect. 63. Part II.

114. From the foregoing Effects of the Mirror, we may with certainty conclude, that to conſtitute Heat in the higheſt Degree, three Things are requiſite; viz. The greateſt quantity of elementary Fire: The cloſeſt Union of its Particles *, and the moſt rapid and violent

* The Diameter of the Mirror was 43 Inches, and

Attrition of them againſt each other; but yet, it is equally certain that neither quantity, motion, nor union, can ſeparately generate ſuch an Effect; but all thoſe Cauſes moſt concur to the production of it.

115. The diſcovery of a more ſubtile elaſtic Fluid than that of the common Air has conducted us to the Knowledge of many Things, which we were for a long time entirely ignorant of.

116. The common Air being the moſt elaſtic of all Things we had any knowledge of before, and that being found to be far from perfectly elaſtic, we ſeemed to lay it down as a certain poſition, that there *was* no ſuch Thing in Nature as a Body perfectly elaſtic; whereas we have now the greateſt reaſon to believe the electric Fluid to be endued with *perfect Elaſticity*, or at leaſt that the Solar Rays are ſo, which ſeem to be only the ſame elaſtic Fluid in a different form.

117. Had not thoſe Rays been perfectly elaſtic, the reflection, reſilition or rebounding of them, after daſhing againſt the face of *Vilett's* Mirror with ſuch great violence, would have very much retarded their Velocity; whereas on the contrary we find the Rays from his Mirror after ſuch a full ſtop, which they ſuffered at the

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the Diameter of the Focus was but ½ an Inch, conſequently the Area of the latter was contained 7396 times in the Area of the former, or as 7396 to 1. See the Propoſition. p. 171.

Face

Face of it, yet burned much more intenſely than thoſe from *Tſchirnhauſen*'s, which were only refracted; and this may tempt us to imagine, that the Rays, by means of ſuch a Rebuff, received an additional Impetus, ſince the Heat ſo much exceeded that of the other, though it was of a larger Diameter than *Vilett*'s Mirror.

118. It may perhaps be objected that *Tſchirnhauſen*'s Glaſs having a greater focal Diſtance, might be a reaſon that the Heat was not ſo intenſe, or elſe that the Cauſe of the difference was, becauſe in the one caſe the Rays paſs thro' another Medium, viz. that of the Glaſs, whereas in the other it was only reflected from the poliſhed ſurface of the Mirror. But ſuppoſing ſuch an objection to be well founded, yet neither of them invalidates the ſuppoſition of a perfect Elaſticity of thoſe Rays, nor that of the increaſe of velocity after being reflected; for if there be two Glaſſes of equal diameter, and focal diſtance, and the one refract and the other reflect, the Effect of the latter will be much greater at the Focus than that of the former, notwithſtanding the Rays in the latter caſe, muſt paſs twice through the Glaſs, *i. e.* Firſt, before they arrive to the poliſhed Metal at the back of the Glaſs, and again when they are reflected back to the Focus; whereas in the former, viz. that of refracting Burners, it paſſeth thro' the Glaſs but once, as I have before remarked.

119. Finding that ſuch a violent Heat was produced merely by the mutual Attrition of the particles of Fire againſt each other, I was no longer at a loſs for a Reaſon, why the Heat of the Solar Rays was ſo much leſs at the ſummits of the higheſt Mountains than at the bottom; on the former of which the Snow remains all the Year, while at the latter the moſt ſultry Heat is produced: For ſince it plainly appears that the *converging* of the Rays or rather their interſecting, is the Cauſe of ſo great a degree of Heat, conſequently their *diverging* *, muſt be the Cauſe of a proportionably leſs degree, as the Effects manifeſtly ſhew.

120. Theſe Speculations were naturally productive of others relating to the ſame Subject, but what principally engaged my Attention was the Uſe and Office of the Sun, which, from the Effects, appeared to be a *Circulator* of Fire; for as he is conſtantly emitting numberleſs Rays from his Body, ſuch a vaſt Conſumption muſt (to maintain an Equilibrium) require as conſtant a ſupply, but of this in the next Chapter.

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* If the Rays of the Sun are emitted perpendicularly from his Surface, parallel Rays, as they are called, muſt be improper Terms, ſince they muſt then be rather like ſo many Radii from the Center of a Circle continually *diverging*.

CHAP.

CHAP. V. PART II.

SECTION. 121.

A new and brief Theory *of the Office of the* Sun; *with Remarks on* Motion.

A certain anonymous Author on the human Soul reasons thus.

122. 'Amidst the numberless Enquiries Mankind have been busied about, that of the Nature of the Soul of Man, the thinking and reasoning Principle within us, either considered in itself, or in a State of Union with the Body, seems neglected or not pursued with Success; and though one might well expect, in these inquisitive Times at least, the Subject should become familiar, yet we find the Accounts we have of it, either from ancient or modern Writers, are most dark and abstruse, or indeed oftentimes quite inconsistent.' And may not I remark?

123. Nor have we much less reason to admire, that the Use and Office of the Sun has not been more considered, particularly when we reflect on the remarkable pains and industry of many of the most eminent and ingenious Naturalists, both ancient and modern, all engaged in the truly laudable Design of cultiva-

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ting the ſublime Science of Aſtronomy, which Study, one ſhould imagine would naturally have conducted them to the Conſideration of that moſt remarkable and conſpicuous of all other Objects in the whole viſible Creation, and which has ſo much the Appearance of the *Primum Mobile* in our Syſtem.

The Magnitude of the Sun.

124. The Diameter of the *Earth* on the ſtricteſt examination being found 7964 *Engliſh* Miles nearly, and that of the *Sun* an hundred times greater, we have conſequently ſufficient Data to inveſtigate *his* other Dimenſions; which are as follow: If the Diameter of the Sun is 796400 *Engliſh* Miles, the Circumference will be 2501970; the Area of the greateſt Circle, or Face of the Sun 498142274784; the ſuperficial Content 1992569099136 ſquare Miles; and the ſolid Content will be 264479674235618688 cubical Miles.

125. What a ſtupendous Maſs this! moſt exquiſitely formed and adapted to the Office for which it was ordained, and with no leſs than infinite Wiſdom! And yet, when we take a general ſurvey of the works of the Creation, we find nothing made in vain; nothing ſuperfluous or redundant; and notwithſtanding this, all is performed (as Sir *Iſaac Newton* has clearly demonſtrated in his Principia) with Mathematical exactneſs!

126. That ſo large a Body was created for Ends

Ends proportionably great, cannot be doubted; and its very ſituation is no ſmall indication of the ſame. What thoſe Ends are, tho' it may be impoſſible ever to find them all out, yet, by proceeding with due caution, we may very probably be able to obtain ſufficient Data to conduct us to many uſeful Truths; and even when the Analogy appears true, and yet falls ſhort of a Demonſtration, it may then be put down by way of Interrogation or Quære, that the ſame Thing may be farther enquired into by others.

127. The next remarkable Characteriſtic relating to that glorious Object, and which is moſt obvious, are the Rays perpetually darting from him: This Phænomenon ſeems to indicate and point out his Office, *viz.* that of a CIRCULATOR. For, as I hinted above, as he is every moment emitting his Beams from all parts of his Body, it may rationally be preſumed, that as conſtant a ſupply of the ſame elementary Fire will be thought abſolutely neceſſary in order to preſerve an Equilibrium.

128. As in Mathematics there is no proceeding forward without proper Data, ſo it fares in Philoſophy; unleſs the Problem have ſufficient Data, the Mathematician labours in vain, and can never inveſtigate his Theorem; no more can the Philoſopher without proper Requiſites inveſtigate his Theory.

129. Arguing from Analogy is an approved method of inveſtigating the Knowledge of Things. Now the Body of Man has been thought

by ſome of the moſt curious Obſervers of Nature, to be analogous to the Syſtem of the World; and was therefore termed the *Microcoſm*, or World in miniature, to diſtinguiſh it from the *Macrocoſm* or great World. Let us then conſider the *Microcoſm* which we beſt underſtand: This minute World we know to be compoſed of Solids and Fluids, and to be full of Motion, and alſo that the Motion of the ſolid Parts (and conſequently that of the whole Machine) is from the effects of the motion of the bodily Fluids; for if their Motion be retarded in any degree, a proportionable defect is ſure to follow among the ſolids alſo; and whenever their motion entirely ceaſes, the whole Machine becomes motionleſs, inanimate, and dead.

130. The next thing to be conſider'd, is, the phyſical cauſe of this natural motion of the bodily Fluids; —— which motion, we are well aſſured, is performed by the *Heart*: An Engine or Inſtrument fitly contrived and adapted for that purpoſe, and placed in the moſt commodious part of the minute Syſtem for that End.

131. If then, I ſay, the ſureſt way to arrive at the Truth, is to argue from Analogy, i. e. from Things well known, to thoſe leſs known; the *Macrocoſm*, or great World is alſo well known to conſiſt of ſolids and fluids, and to be replete with a variety of Motions; which Motions, from repeated Obſervations, appear to be owing to the effects of an active *ætherial*

Fluid:

Fluid: This has been often conjectured before, and insisted on by some of the greatest and most eminent Philosophers, particularly Sir *Isaac Newton* and Bishop *Berkeley*; but as their Reasoning could never be sufficiently supported by proper Experiments before the late Discoveries by Electricity, the Evidences they produced were not properly regarded.

132. From the same method of Reasoning we are naturally conducted to the Sun, as a CIRCULATOR in the *Macrocosm*, which (as we find by the effects of those Burning Mirrors) sends forth such plenty of a powerful ætherial Fluid, or pure elementary Fire.

133. Since then, by this method of Reasoning, we compare great Things with small, may not the Sun with sufficient Propriety be termed the *Cor Mundi* or Heart of the World, similar in its Office to the Heart in the Body, dispensing the ætherial Fluid to the utmost limits of the System *? Particularly when we consider that such a constant emission of that ætherial Fluid from the Sun's Body, must require as constant a supply; how that is performed I am now to enquire.

134. This Fluid, like the Blood in the Body, is from thence returned to maintain the

* The same Doctrine is illustrated by observing that the Tails of Comets are always driven by the Solar Rays to the opposite part of the Comet's Body from the Sun, even after its Perihelion, as well as before.

Circulation: For as the Blood in the *Microcosm* is by the force of the Heart protruded to the utmost limits of the Minute System, and, when it can proceed no farther, returns back to the Heart again to keep up and mantain the Circulation; so, if the Analogy holds good, the æthereal Medium in the *Macrocosm* when protruded to the utmost limits of the system of the World, and can proceed no farther, returns in like manner back to the Sun to maintain the Circulation; by what means such a Return is effected in the *Macrocosm*, I shall endeavour to shew.

135. According to the modern Astronomy, every fixed Star is of the same Nature and performs the same office, that the Sun does in our solar System, which opinion is supported with many rational Arguments, some of which are the following.

136. *First.* The Light of the fixed Stars is not a borrow'd Light, like that of the Planets; but innate, as that of the Sun.

137. *Secondly.* Their distance is so immensely great, as to afford no perceptible annual Parallax, that is, so great that the distance of 162 Millions of Miles (equal to the diameter of the Earth's annual Orbit) nearer or farther from them, makes no sensible difference in their Altitude; neither does a celestial Telescope, which magnifies above an hundred times, make any difference as to their Magnitude, which are undoubted Indications that their distance is immensely

menſely great: And conſequently,

138. *Thirdly.* If the Sun were placed at the ſame vaſt diſtance, it would appear like ſuch another lucid point.

139. Every fixed Star then, being allowed to be the Center of a Syſtem of Planets and Comets, performing the ſame Office of the viſible Sun, and like that perpetually darting off their radiant Beams, to the utmoſt boundaries of each reſpective Syſtem and far beyond; the conſequence muſt be that the profound Abyſs, or what we call the immenſe Void, is moſt replete with Æther of all other parts, that is, that part of Space, which we thought the moſt void and empty, contains the greateſt fullneſs, and the denſeſt Æther, i. e. the farther from thoſe ſeveral Circulators, the more denſe it is conceived to be.

140. To render this yet more plain and intelligible, ſee Plate I. which will convey a more clear Idea than a multitude of Words: Where, the main Plate repreſents the Solar Syſtem; S, at the Center, repreſents the Sun; and the 6 concentric Circles the ſeveral Orbits of the 6 primary Planets. The ſmall Lines or ſtrait Strokes are to repreſent the Solar Rays, the ſame is underſtood of all the reſt, i. e. from the ſeveral ſurrounding Syſtems.

141. Theſe Things conſidered, let us hear Sir *Iſaac Newton* himſelf. *Every Body, he ſays, endeavours to go from the denſer part of the Medium towards the rarer;* ‘ And if this Medium

‘ be

'be rarer within the Sun's Body than at his 'Surface, and rarer there than at the hundredth part of an Inch from its Body, and 'rarer there than at the fiftieth part of an Inch 'from its Body, and rarer there than at the 'Orb of Saturn; I see no reason why the increase of density should stop any where, and 'not rather be continued thro' all distances 'from the Sun to Saturn and beyond. And 'tho' this increase of Density may, at great distances, be exceeding slow, yet if the elastic 'force of this Medium be exceeding great, it 'may suffice to impel Bodies from the denser 'parts of this Medium towards the rarer, with 'all that Power which we call *Gravity*. And 'that the elastic Force of this Medium is exceeding great, may be gathered from the 'swiftness of its Vibrations.' Optics, Quer. 21.

142. These Things, though delivered as a Query, must be allowed to be his real Sentiments, as is manifest from the Advertisement in the 2d. and later Editions of his Optics, where he acquaints us that to shew he did not take Gravity for an essential Property of *Bodies*, he had added one Question concerning its Cause, chusing to propose it by way of a Question, because he was not then satisfied about it for want of Experiments.

143. Thus far Sir *Isaac*'s Opinion seems to coincide exactly with the present Plan. Since then it seems reasonable to suppose that the farther the Solar Rays proceed from him,

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the more denſe they are, conſequently when they have gone on ſo far as to meet with thoſe from the neareſt Syſtems around them, they muſt in thoſe far diſtant Regions be denſeſt of all. Is it not then natural to conclude, that at ſo denſe a part of an extremely elaſtic Medium, it muſt from thence return again to the moſt rare part from whence it was ſent, and in its progreſs, cauſe the centripetal Force of the Planets, i. e. that Force which cauſes them to gravitate towards the Sun? Hence a Circulation in the *Macrocoſm* appears as agreeable with Reaſon, as a Circulation in the *Microcoſm*; and that Gravity is performed by an *impelling* Force.——Is it not reaſonable to ſuppoſe that ſuch a gradual increaſe of the denſity of Æther from the Sun to the utmoſt Limits, is the true mechanical Cauſe, why Saturn in the denſer part of the Medium moves ſlower than Jupiter in a rarer; and again, Jupiter than Mars, Mars than the Earth? *&c.*

144. What a complete, glorious, and ſtupendous piece of Machinery is the Solar Syſtem! How much more ſo is the whole frame of Nature! And how conſummate the POWER, the WISDOM, the GOODNESS of the Divine and incomprehenſible Architect of the Univerſe!

145. Hence there appears another general Cauſe of Motion in the World than what has been commonly ſuppoſed, and an adequate method to render the centripetal Forces of the Planets and Comets intelligible.

146. If we do but caſt an Eye of contemplation on the general Phænomena of Nature, we perceive Motion in almoſt every part. —— That the Matter contained in the viſible Creation is full of *Motion*, is ſo obvious as not to be denied, tho' the mechanical Cauſe of it, and how ſupported and preſerved, has been much controverted. But ſo long as we were ignorant of the *Exiſtence* of active Matter which we have now diſcovered, ſo long we were neceſſarily ignorant of the Cauſe of it: Before a ſubtile Medium or Æther was diſcovered, Motion was given up, along with other immechanical Cauſes, to be performed by the immediate influence of the firſt Cauſe. — Before ſuch Diſcovery, we ſeemed very naturally to conclude that all Matter was inert, whereas we now find we were greatly miſtaken, and that there are active Particles of Matter exiſting as well as paſſive, the effects of which active Particles, particularly thoſe contained in the pores of groſs Bodies, were ſuch, that the groſs Particles *themſelves* appeared (in many different Circumſtances) to be endued with *active Properties.* But had we attended to Sir *Iſaac*'s Principia, we might have learned better; there he informs us, that the ſeeming activity, is not in the groſs Particles themſelves but from the ſubtile elaſtic Medium contained in their pores*. This is indeed a much more accurate Deſcription of it, than could have

* See the laſt Paragraph of his Princip.

have been reaſonably expected at that time, particularly as he confeſſed, he was at a loſs for proper Experiments to prove the manner in which it acted.

147. Nature almoſt every where appears to be replete with phyſical Cauſes to produce all kinds of neceſſary Motions; not only among Animals, Vegetables, *&c.* but even in the celeſtial Regions: — For all motions in the *Microcoſm* both voluntary and natural the moſt ample proviſion is made: And can we imagine a leſs proviſion for Motion in the *Macrocoſm*, particularly now we have made ſo full a Diſcovery of ſuch an active Agent exiſting in Nature as was ſcarce credited before?

148. A principal Cauſe of Motion among inanimate Things is the deſtroying and reſtoring of the Equilibrium —The effects of almoſt every one of thoſe remarkable Experiments in Electricity performed by Dr. *Franklin* *, ſeems to be founded upon Nature's Effort to reſtore the deſtroyed Equilibrium by means of the exceeding Rarity and Elaſticity of the ſubtile Fluid alternately exerting their different and contrary Forces, acting with, or counteracting the ſpring and preſſure of the Atmoſphere. 2dly. Heat and Cold alſo ſeem productive of like effects, which two oppoſite qualities are wonderful: What inſtruments of Force may be worked by the alternate *Powers* (if they may be ſo

* Sect. 65. 66. *&c.* Part I.

termed) of Heat and Cold, witneſs the Fire-engine contrived for raiſing Water out of Mines, *&c.* the operation of which is begun and continued by no other artificial means than thoſe two Oppoſites alternately produced; *viz.* firſt, a Heat which deſtroys the Equilibrium, and again, that Heat checked with a ſudden Cold to reſtore it.

149. The Effects of thoſe two Oppoſites in *Nature*, were, as before obſerved, of ſuch weight in the eſteem of the great Lord *Bacon*, that he compared them to her two Hands; how much more then had he lived to ſee the wonderful effects of Oppoſites, which are brought about by thoſe two inherent Qualities of this grand Principle of Nature, namely, exquiſite Rarity and Elaſticity in the Medium juſt diſcovered?—— Theſe and many other indications, conſpire to point out a univerſal Motion throughout all Nature, of which this ſubtile Medium is the undoubted Cauſe.

150. Thoſe who had rejected ſuch a Medium, and conſequently ſuch a manner of Reaſoning were much diſtreſſed for the Cauſe of ſuch a Motion, having thereby ſhackled themſelves with inſuperable Difficulties and Inconſiſtencies, as will manifeſtly appear by the following Tranſcript.

151. ‘ Among ſecond Cauſes, Motion is the ‘ principal immediate *Agent* and *Inſtrument* of ‘ all the Effects, Operations and Phænomena, ‘ that are produced in the material Univerſe,

'and is the primary *Cauſe* upon which the 'Power, Force, and Energy of every Body, or 'Syſtem of Bodies wholly depends. For Mat-'ter, or Bodies without Motion, can neither 'ſuffer any change in themſelves, nor pro-'duce any change or alteration in other Bo-'dies, but would remain for ever in a ſtate of 'abſolute Reſt and Inactivity; ſo that what-'ever changes or mutations happen in Bodies, 'the ſame are all neceſſarily produced by Mo-'tion, either added thereto, or ſubtracted there-'from. For which Reaſon we find, that ac-'cording to the preſent eſtabliſhed order of 'Nature, Matter and Motion are rendered in-'ſeparable; the whole Syſtem of Matter, and 'all material Beings, both animate and inani-'mate, being for ever ſubject to ſome degree 'of Motion, more or leſs, by which they are 'kept in a continual Circulation and Fluxion, 'and thereby fitted to undergo and paſs thro' 'different States, Forms, Periods, and Ap-'pearances, according to the final Ends, and 'Appointments of Providence. And thus we 'obſerve, that all animal and vegetable Bodies 'from the higheſt to the loweſt degree in the 'Scale of Life, as well as all other material 'Beings, even the great Planetary and Come-'tary Bodies themſelves, which compoſe this 'Solar Syſtem, are conſtituted and formed to 'continue only for a certain Revolution and 'Period, ſome longer, ſome ſhorter, which is 'no other than a progreſſive Motion, whereby

'they pass through different Scenes and States, 'and put on different Forms, and Appearan- 'ces, which when accomplished, they become 'resolved again into the general elementary 'Mass of Matter, though even then they are 'neither divested of Existence, nor Motion, 'but are still in a Progression to new Life, 'Form and Being.' — See the Introduction to Mr. *Stephenson*'s Mechanical Physician, p. 11.

152. Is not such an Account of Motion somewhat extraordinary? For according to this; Motion is both Cause and Effect. *Motion is the immediate* AGENT *and Instrument of all Effects, and the primary* CAUSE *upon which the Power, Force, and Energy of every Body, or System of Bodies wholly depends.* But must not there be an instrumental Cause of Motion itself? Is the Motion of a Wheel, for Instance, the Cause of the Power and Force of the Hand that turns it; or is the Force of the Hand the Cause of the Motion of the Wheel? — The Answer is so obvious, that no sober Man would be so absurd as to hesitate about it.

153. Sir *Isaac Newton* in the last Paragraph of his Principia, had pointed out an adequate Agent, as the instrumental Cause of Motion, which some of his pretended Disciples industriously robbed of Existence. The subtile Fluid, which his great sagacity had discovered was contemned and rejected as an imaginary Fluid only; and that their Readers might be sure to understand it as such, they put it down

among

among their explanation of Terms *. And yet, when they had fet afide his mechanical Agent, the Matter was fo far from being mended, that it was thenceforward rendered fo unintelligible, as, that Motion itfelf muft either be the Caufe of its own Motion, or elfe that the Power and Influence of the Deity is more immediately interefted in it than in moft other Things.

CHAP. VI. PART II.

SECTION 154.

Oppofites a principal Caufe *of very confiderable Operations of* Nature.—*Account of the* Freezing *of Quickfilver.*

IF we take but a fuperficial furvey of the feveral Operations and Phænomena of Nature, we fhall be foon convinced that not a few of them are effected by means of deftroyed and reftored Equilibriums, more particularly with regard to Motion: For which Reafon fhe feems to be plentifully provided with Oppofites to act as Antagonifts. Almoft every Mufcle of an Animal has its Antagonift Mufcle to move the feveral parts of the Body; and thefe, as we experience, are fo exquifitely contrived, that the motions peculiar to them can be exerted by a mere Thought, while others

* Section 101, Part I.

ſeem to act ſpontaneouſly, or naturally, ſuch as the periſtaltic Motion of the Inteſtines and many others. Were we unacquainted with this, there would be no rational Way left whereby to account for *Animal* Motion.

155. The Motion of the *Fluids* alſo appears to be performed by the ſame kind of Mechaniſm as thoſe of the Solid parts. By means of the alternate dilatation and contraction of the muſcles of the *Thorax*, for inſtance, the external Air paſſeth and repaſſeth into, and out of the Lungs: When the Thorax is dilated, the Equilibrium is in ſome meaſure deſtroyed, and at the ſame time is as inſtantaneouſly reſtored by the preſſure of the Air into the Lungs; which, is no ſooner there, but a total ſeparation is made. The Fire, or active and enlivening part of it, eſcapes into the Blood to keep up the Motion of it, while the remaining noxious particles are expelled by the ſucceeding contraction of thoſe Muſcles; and thus the Motion of the bodily Fluids is generated and maintained, *viz.* by oppoſite Powers which alternately deſtroy and reſtore the Equilibrium. The ſtrong dilatation and contraction of the robuſt Muſcles of the Heart are undeniable Indications that they were contrived for the ſame End.

156. Similar contrivances are often applied by the human Artiſt, particularly when he employs the powers of Art in a proper ſubſerviency to thoſe of Nature, ſkillfully directing her contrary Efforts to one uniform End, as is veri-

fied

fied in Engines for raiſing Water, *viz*, Pumps, *&c.* who, having diſcovered that the ſpring and preſſure of a column of the common Air is equal to the weight of ſuch another column of Water, conſiſting of upwards of 30 Feet in height, wiſely conſidered that to make the ſame power of Nature ſubſervient to himſelf, he had no more to do than contrive a method to produce a Vacuum of the ſame Height, *viz.* 30 Feet, ſince then it might be applied to many uſeful purpoſes.

157. Hence oppoſite Powers ſeem ordained as things neceſſary, and particularly, to deſtroy and reſtore Equilibriums*, and thereby to maintain a univerſal Motion† throughout the bounds of Nature.

158. Having already ſhewn the *greateſt Degree of Heat* that ever was produced, and the means by which it was effected, I ſhall now enquire into the method by which the *ſmalleſt Degree of Heat* has been obtained.

N. B. I make uſe of the expreſſion, *ſmalleſt Degree of Heat* inſtead of the greateſt Cold; for ſince Cold is only a privation of Heat, and both of them are relative with reſpect to our Senſation; that which is above the Heat of the human Body being termed hot, and that below the ſame degree, cold; conſequently the ſame degree of Heat may ſeem very different if applied to different parts of the very ſame Body: The Term therefore, Cold, would only ſerve to

* Part I. Sect. 235. to 241. † Part II. Sect. 153.

perplex

perplex the Subject; since there is, strictly speaking, no true mean to be found between what we term Heat and Cold.

159. In order to introduce this Head of discourse, I must take notice that Professor *Boerhaave*, when reasoning on Fire, and treating on the Motion of it, says,

160. 'There is still another Motion which 'I ascribe to Fire, which is the constant effect 'of its proper agility; and this is most evident'ly demonstrated by undeniable Observations. 'Let us, for instance, consider Water when it 'is 33 degrees cold, and it will then be in its 'coldest State; that is, it will contain as small 'a portion of Fire*, as in the nature of Things 'can possibly reside in pure Water; for if this 'simple Water be affected with a greater de'gree of Cold, it will not continue Water any 'longer, but be converted into a pellucid brit'tle substance, called Ice, tho' reducible again 'to Water by a Heat of 33 Degrees: Hence, 'therefore, it appears evident, that Water is 'Water only by the motion of the Fire resi'ding in it, and that it is not Water from its 'own Nature considered separately and alone. 'The same is true of Glass, Fossils, Sulphurs, 'Semi-metals, Metals, and perhaps of all other 'Bodies, which appear in a consistent Form in a 'smaller degree of Heat, but are put in fusion, 'and converted into a kind of Water, if the

* Heat.

'same

'same is increased to a certain degree, which
' will be different, according to the various
' Natures of the Substance under Examination.
' Since therefore, by *Fahrenheit's* Thermometer,
' the natural Heat has been observed 32 de-
' grees below the freezing Point, hence we see
' evidently, that thro' all this difference of 32
' degrees, the Fire was agitated with a Motion,
' that grew gradually less and less, but was ne-
' ver totally destroyed; and therefore, even at
' that time, when all Animals and Vegetables
' perished through the excess of the Cold, the
' Fire was not absolutely at rest. Therefore,
' we may safely assert, that the Fire was even
' then in Motion. But, as it appears from Ex-
' periment, that this Fire may be diminished
' artificially still 40 degrees more, we are hence
' certain, that Fire, in the greatest natural Cold
' possible, is agitated 40 degrees more than it
' is in this artificial one, and that again, through
' every intermediate degree, it is continually
' dissolving some Bodies, which a little after, in
' a smaller degree of Heat, appear of a solid
' consistence. Fire, therefore, is perpetually
' agitated in the greatest Cold, and still gradual-
' ly more and more in every increase of Heat;
' and consequently, is always in Motion.'

161. But there is another fluid Substance, not yet taken much Notice of, which requires the greatest degree of Cold of all others to convert it into a solid; namely, that of Quicksilver; which is of late Years, found to become so by

means of a certain degree of Cold, as well as Water and many other Things. — See, *An Account of artificial Cold produced at the Royal Academy of Sciences at* Peterſburgh; *by Doctor* Himſelf. *In a Letter to Doctor* De Caſtro. F. R. S. *Tranſlated from the* French *by* James Parſon'*s*, M. D. F. R. S. *from the Philoſophical Tranſactions.*

N. B. The following Account of the particulars, I met with in the St. *James*'s Chronicle, or *Britiſh* Evening Poſt, of which the above, is put at the beginning, as a Title to the Account, the top of that Chronicle being unluckily cut off: But by what I could make out from other parts of the Paper, it was for the Month of *July*, or beginning of *Auguſt*, 1761, on the firſt and ſecond Columns of the Second Page of the Chronicle.

162. That Account being of a conſiderable length, I ſhall take notice only of ſome of the moſt remarkable parts of it.

163. *Peterſburgh.* ‘On the 25th of *December* 1759. in the Morning between Nine and ‘Ten, *De Liſle*'s Thermometer was at the ‘199th degree of Cold; and Mr. *Braun*, as ‘well as Profeſſor *Æpinus* repeated an Experi‘ment, that had been made before with a ‘freezing Mixture, in which Experiment the ‘Quickſilver in the Thermometer had been ‘frozen. As ſoon as the former had obſerved ‘the Quickſilver immoveable in the Thermo‘meter, he broke the Glaſs, and found, to his

‘amazement,

'amazement, the Quickſilver frozen, but not
'entirely; for in the middle of the Glaſs Ball
'there was a ſmall portion yet remaining Fluid.
'Mr. *Æpinus*'s Thermometer fell (when in
'the Mixture) with extreme rapidity, almoſt
'to the 500th degree and in breaking the Glaſs
'from below, he found the Quickſilver con-
'tained in it, abſolutely frozen. Both the Gen-
'tlemen found, that the Quickſilver, thus ren-
'dered ſolid, bore hammering and extenſion
'like other Metals; but being afterwards ex-
'poſed to the open Air, it recovered its former
'Fluidity in a little time.'

164. 'Mr. *Æpinus* went ſomewhat farther,
'in order to examine the Quickſilver when
'made ſolid: He poured Quickſilver into a
'Glaſs Tube as thick as one's Finger, cloſed
'at the bottom but open at top. The Quick-
'ſilver in this Cylinder, which was about one
'Inch and half long, froze in three Quarters
'of a Minute; and he obſerved that it became
'ſolid, perfectly reſembling other Metals, ex-
'cept Iron: It continually contracted, and its
'Surface, which was at firſt pretty high, ſoon
'ſunk very low. This Cylinder of frozen Quick-
'ſilver ſunk to the bottom of the Fluid Quickſil-
'ver, in the ſame manner as is obſerved of other
'Metals except Iron. We know the contrary
'happens with regard to Water and other
'Fluids, when frozen, which extend as they
'become ſolid, and their Ice ſwims in the Fluid
'Matter of which they were produced.'

165. 'On the 26th of *December* in the 'Morning, between Nine and Ten, the Cold 'became exceeding ſharp, and ſuch as exceed'ed the greateſt degree of artificial Cold fixed 'by *Fahrenheit*; *viz.* 40° below *Zero* in *Fahren'heit*'s Thermometer, is equal to 210 degrees 'of that of *De Liſle*.'

166. 'Mr. *Braun* repeated this Experiment 'again, exactly with the ſame ſucceſs, with 'that of the Day before. The Counſellor and 'Profeſſor *Lomonoſlow* made that ſame Experi'ment on the ſame Day; and by means of 'Aqua fortis, the Cold came to 495°. He then 'poured in Spirit of common, or Sea Salt, and 'the Quickſilver fell down in the Thermo'meter to 554°, and in taking the Thermometer 'from the Mixture, the Quickſilver continued 'to fall in the open Air to the 552 degree.'

167. The Proportion of *De Liſle*'s Thermometer and that of *Fahrenheit*'s are, ———— As 210: 40:: 554: 105,5 — i. e. 554 degrees of *De Liſle*'s Thermometer, is equal to 105,5 of *Fahrenheit*'s; ſo that the artificial Cold produced at *Peterſburgh* would, inſtead of 40 below the freezing Point, have reduced *Fahrenheit*'s Thermometer 65,5 degrees lower, that is $40^{deg}+65,5^{d}=105,5^{d}$.

168. Or to ſpeak more intelligibly, when the Mercury begins to freeze, if *Fahrenheit*'s Thermometer be at 105 degrees, and when the Water begins to freeze, it is but 32 or 33, conſequently the Motion and Heat of Fire con-

tained

tained in each, will be as thoſe Numbers; that is, the ſmalleſt degree of Motion and Heat, which is juſt ſufficient to melt the ſolid Quickſilver, and the increaſed Motion and Heat, which is juſt ſufficient to melt the ſolid Water, are as the Number 105,5 and the Number 32 or 33.

169. From ſuch a Method of Reaſoning, we may conceive all the different degrees of Motion and Heat in agitated Fire, from the leaſt to the greateſt, that is, from the ſmalleſt degree of the Motion and Heat of Fire which melts the ſolid Quickſilver, even to the greateſt imaginable, namely, that ſurpriſing degree of Motion and Heat which is produced at the Focus of *Vilett*'s Mirror.

170. Is not this a more intelligible way of arguing, than that of Heat and Cold? For as it is allowed that Heat is only relative, i. e. the Heat which is leſs than that of the human Body, we term cold, and that which exceeds ſuch Heat, we call hot. Heat and Cold therefore cannot be ſo juſt a diſtinction, as to term them different degrees of Heat; becauſe it is not a little difficult to know where to place the *Zero* (or 0) on the Thermometer, to point out where the Cold begins. If this definition of Heat be diſliked on account of the diſtinction only, I ſhall be much indebted to any one, who can ſhew where to fix the ſtandard on the Thermometer, *viz.* where the Cold ends, and the Heat begins. ——— Hence appears the abſolute neceſſity of making

making choice of the moſt adequate Terms, and explaining them.

171. From theſe Experiments of freezing Quickſilver, it appears, that were it not for ſome degree of motion, and conſequently of Heat, there would be no ſuch thing in Nature, as a common fluid; but inſtead of Quickſilver, another white malleable Metal; and inſtead of Water, a tranſparent, ſolid, brittle ſubſtance, or another kind of Glaſs.

N. B. The foremention'd freezing mixture was made with Spirit of Nitre combin'd with Snow.

172. Mr. *Æpinus* has found that the Experiment is very eaſily and ſpeedily made in the following manner:

173. Take Spirit of Nitre, cooled as much as poſſible, and with it, half fill a Wine-glaſs, throwing in at the ſame time as much Snow, and ſtirring it till it becomes of the conſiſtence of pap: Then you have, almoſt in an inſtant, the neceſſary degree for the congelation of the Quickſilver. Others will have it neceſſary to uſe fuming Spirit of Nitre, or ſuch as is evaporated till the Fumes become red.

N. B. A more full Account of this freezing of Quickſilver is ſince publiſhed in the Medical *Muſeum*, to which I refer my Reader.

174. And now I ſhall put a Period to theſe my promiſed Animadverſions on *Fire*; in the inveſtigating of which abſtruſe Subject, if I ſhall be thought by any to have wandered too

far

far out of the common path, I desire it may be imputed to my anxious pursuit of, and sincere regard for *Truth*, which I have all along endeavoured to keep in view, and hope, that I have at length attained it, by the seasonable Assistance of unbiassed Reasoning, and fair Experiments.

The End of the SECOND PART.

The THIRD PART.

CHAP. I.

A Philoſophical Miſcellany.

Being a new Plan of Philoſophy, *founded on the late diſcover'd* Subtile Medium, *and countenanced by the Authority of a very ingenious* modern Author.

SIR Iſaac *Newton,* that great Pattern of Order and Method, when he had finiſhed the *firſt* and *ſecond* Books of his Principia, proceeds to his *third,* by giving a brief account of the former ones.

2. 'In the preceding Books I have laid down 'the Principles of Philoſophy; Principles, not 'Philoſophical, but Mathematical *; ſuch, to

* *Viz.* accurate Mechanics. For thus reaſons that great Author:

'To practical Mechanics all the manual Arts 'belong, from which Mechanics took its name. But 'as Artificers do not work with perfect accuracy, 'it comes to paſs that Mechanics is ſo diſtinguiſh'd 'from *Geometry,* that what is perfectly accurate is

'wit, as we may *build our* Reasonings upon *in* 'philosophical Enquiries*. These Principles are, 'the *Laws* and *Conditions* of certain Motions, 'and Powers or Forces, *which chiefly have re-* '*spect to Philosophy. But lest they should appear* '*dry and barren, I have illustrated them here* '*and there* with some philosophical Scholiums, 'giving an account of such things, as are of 'more general nature, and which Philosophy 'seems chiefly to be founded on; such as the 'density and the resistance of Bodies, spaces 'void of all Bodies, and the motion of Light 'and Sounds. *It remains* that from the same 'Principles, I now demonstrate the frame of 'the System of the World,' &c. &c.—Princip. Lib. 3d. p. 200.

3. Here I can only add a fruitless tho' hearty wish, which is, that I were capable of imitating so bright a pattern of methodical Accuracy; or rather that we had at this Time a *second* Sir *Isaac*; for since the *first* was able to deduce very surprising effects from the *Laws* only, observ'd by Bodies in Motion; how much greater might be accomplished by a Genius

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'call'd Geometrical and what is less so is call'd 'Mechanical: But the errors are not in the Art 'but in the Artificers.' Hence Geometry, i. e. Mathematics, is mechanical in the strictest Sense, and *Mathematical* Philosophy and *Mechanical* Phylosophy, are synonymous.

See the former part of the *Preface* to Sir *Isaac's* Princip.

like

like his, from the actual Discovery of the first *Principle* it self, the very cause of all those mechanical Motions realized to our Senses? And I may add, how happy shall I think myself if I can escape Censure for endeavouring to become a faint Imitator of so illustrious an Original?

4. From the *first* of the two foregoing Parts it appears, that the electrical Fluid is a much more subtile elastic Medium than that of the Atmosphere; and that it exhibits all the most remarkable Indications of Universality. And from the *second* Part it is as evident, that Fire is a permanent Principle: Nor can there be any room to doubt of its being formed at the first Creation, as well as other Things.

5. But as this is contrary to the received and present established Philosophy, which has rejected and excluded all Mediums more subtile and elastic than the common Air, and also Fire, as a permanent Principle; it is therefore expected that this little Treatise will meet with some Opposition, if thought worthy of notice. But, as these assertions are founded on undoubted Truths, tho' such as we were 'till now entirely ignorant of, the search of Nature was attempted in vain*; mechanical Principles were exploded, and immechanical ones substituted in their stead, which resolve all Effects into the immediate Influence of the first Cause.

6. But as the grand Desideratum is now dis-

* *Preface* to the Princip.

covered, 'tis to be hop'd that the beautiful order and harmony, i. e. the Mechanism of Nature will soon be render'd much more intelligible than ever it was capable of being made before; and that such a rational Philosophy will soon be establish'd, which supposes, 'The 'whole frame of Nature to be a perfect and 'well regulated Machine. In other Words, 'that the visible System of the World, created, 'disposed, and set into Motion by the finger 'of God, acts as a Machine does; a connec- 'tion and communication being preserved be- 'tween all the distant parts of it; for if the 'contact of a Machine be interrupted, the 'motion is destroy'd in all those parts from 'which the communication is cut off. More 'particularly such Philosophers assert that 'the Fluid Ætherial Matter of the Heavens 'acts by impulse on the solid Matter of the 'Earth, is instrumental in every one of its 'Productions, and necessary to all the stated 'Phænomena of Nature.'

7. However, the method to conduct us to such kind of reasoning, and the manner of our researches will now be *inverted* and contrary to the former Order. — Before the Discovery of a subtile Medium was made, the only rational way to proceed in the *researches of Nature*, was *a posteriori*. But since the active principle, *viz.* the grand mechanical Cause is discover'd, we may now with equal Propriety, reason *a priori*, if Sir Isaac *Newton* himself is allowed to

be

be a competent Judge; who in the 13th Propo-sition of the 3d. Book of his Principia remarks,

8. *We have discoursed above of these Motions from the Phænomena. Now that we know the Principles on which they depend, from these Principles we deduce the Motions of the Heavens* a priori. *Because the weights of the Planets towards the Sun are reciprocally as the squares of the distance from the Sun*'s *Center.*

9. Thus we are instructed by that great Master of Science how far we are to proceed in the researches of Nature, *Analytically*, before we attempt the *Synthesis*, i. e. before we can Reason *a priori*.——As we know the Principles, says Sir *Isaac*, *on which the Motions depend, we deduce the Motions of the Heavens* a priori. What those First Principles were, he informs us in the next Words, *viz.* the weights of the several Planets, (that is, their Gravity) towards the Sun are reciprocally as the squares of their several distances from the Sun's Center.

10. Here it is to be observ'd, that this fundamental Principle of Sir Isaac *Newton* was only a *Law*, which he discover'd to prevail in the Motion of the Planets: This *Law* is the *Principle on which the Motion of the Planets depends*. No one besides that renown'd Philosopher ever yet attempted to discover such a *Law*, who succeeded in the Attempt. What *Keplar* hinted, Sir *Isaac* only was capable of compleating. As to the Principle itself, *viz.* the Existence of a subtile Medium, which was the Cause of

that

that Law obſerv'd by Bodies, it was not then demonſtrable. That which is now moſt eaſily accompliſhed by every Novice in Electricity, was at that time beyond the reach even of the great Sir *Iſaac* himſelf.

11. It remains that I now enquire more particularly into the ſeveral Uſes, that this extenſive Agent is ordain'd to ſerve in the World. And firſt, let us conſider it with reſpect to mechanical Agency, that Life and Spirit, as it were, of all the varied Operations of Nature. —— But as this Subject has been lately diſcuſſed with very great Judgment by a maſterly Pen, I have faithfully extracted the moſt curious and material Paſſages for the Information of my Readers, who have not peruſed them before, and I imagine thoſe who have, will hardly grudge the critical Remarks that Author has made, a ſecond, or a more repeated Reading.

12. The Treatiſe I mean is entitled, An Eſſay on the firſt Principles of natural Philoſophy, by the Rev. Mr. *Jones*, Printed at *Oxford*, 1762.——That ingenious Writer introduces his accurate Obſervations in the following pious and ſpirited manner.

CHAP.

CHAP. II. PART III.

SECTION 13.

Abstract of Mr. Jones' *Essay.*

"GOD having created the World for the Benefit of all Mankind, every Man has a natural Liberty of enquiring into the Structure of it, and of examining the various motions that appear in it, with their several Dependencies, Circumstances and Causes; a study highly commendable, if consider'd only as an inexhaustible fund of innocent amusement, but worthy of a better Name, when applied to its proper use: For, if it be not our own fault, we may, *out of the good things that are seen, know him that is*; and *by considering the Works,* be led to *acknowledge* the Power, Goodness and unspeakable Wisdom of the *Workmaster.*"

14. "In this Enquiry, tho' a Man may reap many advantages by seeing with the Eyes of others, who could see farther than himself, and is greatly to be blamed if he does not make use of the opportunity; there is certainly no Law that obliges him to keep his Eyes shut, where his own safety and satisfaction require him to open them. The Constitution of the World, together with the Powers, Causes or Principles upon which the Operations of Nature depend, being

being matters of fact, and not points of ſpeculation, it is *Evidence* alone that can lead us to any rational determination."

15. "My deſign at preſent therefore, is to collect as much of this Evidence as the caſe can reaſonably be thought to require, and lay it before the Public, without any regard to the ſyſtematical Reaſonings, or reputed Authority, of this or that Philoſopher in particular. In the proſecution of this deſign, I ſhall endeavour to expreſs my Mind with freedom and impartiality, as a Man ought in conſcience to do, who has no private ends to ſerve, and does not deſire that the value of what he has written ſhould be determined by the favour of his Friends, but rather that his Enemies, if he has any, would rigorouſly compare it with their own Obſervation and Experience."

16. "If we are not free from thoſe vulgar prejudices,—— *That it is a great Misfortune to be ſingular,*—— *That the Multitude, (who have been always changing) muſt neceſſarily be in the right,*——— *And that the laſt Writer, who has obtain'd a Name in any Subject, is to be follow'd implicitly in every thing he has propounded,* we ſhall be afraid to *enquire,* and to endeavour to advance the progreſs of true and uſeful Knowledge, as we all profeſs to do, and all ought to do; but ſhall rather fall upon the fruitleſs Labour of accommodating every new Diſcovery to the Principles we have already receiv'd, looking at the ſame time with a ſuſpicious Eye on eve-

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ty Writer, who with regard to any particular Article, would turn us out of the beaten track. An ancient Maxim of the once celebrated *Thomas Aquinas*—— *Cave ab illo qui unicum librum legit*,—— deserves to be considered by all those, who dare not venture abroad in quest of truth, but behind the back of their Tutor; in which situation, they may possibly see so much of *him*, as to be able to see nothing else."

17. "It will readily be granted, I suppose, that such a practice as this is very childish and absurd, provided the Observation be applied only to the Prejudices which once reigned in favour of *Aristotle*, *Des-Cartes*, or the *Chymists*; yet it so happens, that if an Author comes home to his own times, and ventures to look into any of the pretensions of the present Age, he is in danger of being assaulted by all that meet with him; and generally with the greatest vehemence by those who are the most superficial in their Knowledge."

18. "This Consideration, I frankly confess, hath sometimes had so much weight, and appear'd so formidable to me, that I have been almost tempted to throw my Pen into the Fire, rather than employ it against any current Opinion. A sincere Love however of the Science of Nature, and a confirm'd persuasion both of its usefulness and its importance, ought to prevail against these difficulties; and they have prevailed with me, to try, in the first place, if I can dispel some of that learned darkness with

ter comprehended within this viſible World, is full of motion; and the learned have very greatly doubted, by what means, and after what manner, this Motion is ſupported and preſerved. Some of them, according to their own accounts, begin with the two Principles of *Matter* and a *void Space*. To their Matter they give this capital *Law*, that if once moved, it ſhall continue in Motion, becauſe it has no power to *ſtop it ſelf*. Thus they elude the neceſſity of providing any *phyſical* Cauſe for the conſervation of motion, and ſave themſelves all that trouble, which they might otherwiſe have in ſearching after it. Then, from the Principle of a *Vacuum*, or ſpace void of all ſenſible Matter, they propoſe the two following advantages; that a Body will have *room* wherein to move, and that being once ſet a going, there will be nothing in the way to obſtruct or diminiſh the quantity of its motion."

23. "In this manner they account for the continuance of that Motion which is rectilinear: But then for the producing of other motion in curves and compounded directions, with which Nature is obſerv'd very much to abound, they ſuppoſe an emiſſion of immaterial virtues or forces, propagated thro' their *Vacuum* from one parcel of matter to another far diſtant from it. Theſe virtues are of two ſorts: By the one of them, one Body is ſo affected by another, as to be *drawn nearer* to it; by the other, it is cauſed to recede from it; And neceſſity re-

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quires upon ſome occaſions, that the ſame parcel of Matter be allowed, and that in all its component parts, to have both theſe Powers, tho' contrary to, and deſtructive of one another. The names by which they have been diſtinguiſhed in different Ages are *love* and *hatred*, *ſympathy* and *antipathy*; and now they paſs current under the faſhionable terms of *Attraction* and *Repulſion*. But I preſume if we were to call them *a pulling without any hold*, and *a puſhing without touching*, we ſhould deſcribe all the ſenſe they have, as well as diſtinguiſh one from the other. How or when theſe qualities came into the world, and *what* they really are, this ſort of Philoſophy thinks itſelf not concerned to declare; but only to affirm that there *are* ſuch; and if preſſed either with difficulties or abſurdities, has this to offer in its defence, that the World is over-ruled by a ſupreme intelligence, which can act in *any manner*, and which appears from ſome obſervations to act in *this* manner."

24. "Theſe are ſome of the outlines of that coſmographical Syſtem, which was taken up, and cultivated with all the geometrical Skill of the great Sir *Iſaac Newton*; who, as an honourable Author has truly obſerved of him, *was made by nature and inclination for mathematical Studies* *. Moſt of our celebrated Mathematicians, who are led by a natural bent to a like

* See the Life of Dr. *John North*. p. 260.

method

method of reasoning, are confident, that he has transfused into physical Subjects the certainty of geometrical demonstration. Hence they tell us, he *has secured his Philosophy from the hazard of being disproved*; and have accordingly bespoken all the *Discoveries* that shall happen to arise in *future Ages*, which, it seems, are to *confirm and enlarge his Doctrines, but can never refute them* *. Whether the case does in all points come up to their description of it, we shall be better able to judge, I hope, from the Contents of the following sheets."

25. The *sacred Writings* agree to *that Scheme of Nature*, which my very late Quotation from this Author † prevents the Repetition of here; to which he adds in this *Section*, "That the most ancient Heathens were in Possession of that Knowledge; The *Elements* in their Hands had a Principle of Intelligence ascribed to them, and were taken for the *Gods that govern the World*: But with those who are taught, that the *true God* is distinct from, and above the World of Matter, tho' virtually present in it by a providential Inspection and Superintendence, it will only serve to enlarge their Ideas, by setting before them the visible Evidence of that Divine Wisdom, which, with so exquisite a Contrivance, and such a Simplicity of Design, hath adapted physical *Causes* to the production of their respective Effects; it will introduce them

* See *Maclaurin*'s account of Sir Isaac *Newton*'s Discoveries. † See *Section*, 6. p. 259.

to a Knowledge of *Things*.——— *Des-Cartes* was of Opinion, that the World is directed by some subordinate and mechanical Causes. In which he seems to have been right only by accident; for as to the kind and quality of these Causes, he searched no farther than his own Brain, and neglected those undeniable Phænomena, with which his Causes are not to be reconciled."

26. "Sir Isaac *Newton* on the other hand, was very diligent in studying those Phænomena, which belong chiefly to the Class of natural *Effects*; in the adjusting of which he makes a great figure; but unhappily solves the whole government of the created World by a *nostrum*."

27. "The Followers of *Newton* and *Des-Cartes*, having thus admitted something which is arbitrary in the very foundation of their Schemes; we can never expect to see their disputes brought to any issue, so long as there are Men equally learned and ingenious on both sides to perpetuate them."

28. "While these able Philosophers are contending with each other, some in the pursuit of fame, and others in the pursuit of truth, without being able to agree where and with whom it is to be found, I should not dare to interpose in such a subject, unless I suspected natural Philosophy to be a much easier Thing than they have made of it; such, as a plain Man, who only consults the proper evidence, and pretends to no more Wisdom than the rest

of Mankind, may be able to ſtrike ſome light upon. This however cannot be done in ſuch a manner as to be attended with any good Effect, till it is firſt determin'd, whether the Operations of Nature are immediately owing to mechanical Cauſes; or whether they are conducted after a manner unknown to us in empty Spaces."

29. "The Writings of our modern Reaſoners, whether Metaphyſicians or Mathematicians, are ſtored with Objections, not only againſt the reality, but even the poſſibility of a *mechanical Agency*. To theſe their Objections, I ſhall now addreſs myſelf particularly, and endeavour to ſhew, that not one amongſt them all is of any force. As to their *Prejudices*, I do not undertake to remove them; but leave it to time and a farther Knowledge of Things, to wear off all ſuch Impreſſions as will not bear to be reaſon'd with."

CHAP. III. PART III.

SECTION. 30.

Abſtract of Mr. Jones' *Eſſay continued.*

THE *ſecond* Chapter of that Author's ingenious Treatiſe contains a vindication of the mechaniſm of the World, and proves by the moſt ſatisfactory Arguments, that the Operations of Nature are performed by ſecondary Cauſes, or inſtrumental means.

31.

31. He calls it a Reply to the principal Objections in Dr. *Clarke*'s Letters to Mr. *Leibnitz*. — "It will be allow'd me, ſays he, that the celebrated Dr. *Samuel Clarke*, when he undertook to defend the *Newtonian* Philoſophy againſt Mr. *Leibnitz*, an able *Carteſian*, underſtood what he was diſputing about, and hath ſaid the beſt that was to be ſaid on the occaſion. If this ſhould give but little trouble, we have not much to fear from any Body elſe. He has brought together ſeveral Arguments againſt the Doctrine of a general Mechaniſm in Nature; the firſt of which, if it can be called an Argument, conſiſts in barely aſſerting the *impoſſibility* of it. *Certain Portions of Matter*, ſays the Dr. are obliged to follow each others Motions by an adheſion of *Parts*, *which no* Mechaniſm *can account for* *."

32. "Now that the *Parts* of Bodies are made to *adhere* together, and ſome of them very ſtrongly, is an undoubted Matter of Fact; ——— that *no Mechaniſm can account* for this, or that it cannot be occaſioned by the action and preſſure of ſome *mechanical Agent*, is what Dr. *Clarke* ought to have *proved*: Inſtead of which, he takes it for granted; and would put the labouring Oar into the hands of his Adverſaries. For having mention'd this Opinion to Mr. *Leibnitz*, *viz.* that the continuation of Motion in the heavenly Bodies,

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* Collection of Papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

the formation of Plants, &c. are mechanical Operations: *Whoever*, fays he, *entertains this Opinion is, I think, obliged* in reafon *to be able to explain* particularly, *by what Laws* of Mechanifm *the Planets and Comets can continue to move in the* Orbs *they do through* unrefifting Spaces; *and by what mechanical Laws both Plants and Animals are formed**."

33. "But this is the ftrangeft Tafk that ever was impofed fince the Labours of *Hercules*: For we muft firft allow this Author to *empty* the celeftial Spaces of all matter, and then fall to work to account for the Motion of the Planets in thefe fpaces by *Mechanifm*: And we muft do it *particularly*, fo as to give general Satisfaction, without failing in a fingle Article. If thefe Spaces be void of all *refifting* Matter, it follows of courfe that they are alfo void of all *impelling* Matter; for the Fluid that cannot refift in fome cafes, will never be able to impel in others. So that this *reafonable* Demand, as he thinks it, is no other than this——We are to explain all Things *mechanically*; but then we muft take care to do it *without Mechanifm*. It is not the method of a fair difputant, to require an Adverfary to difarm himfelf, and to fubmit to fuch a ftate of the cafe, as will render it impoffible for him to fucceed, and prove him to be very weak indeed, if under fuch circumftances he fhould ever fet about it."

* Collection of Papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

34.

34. " Besides, there is a great want of perspicuity in Dr. *Clarke*'s way of expressing himself; it being hard to conceive, how the Motion of a Planet or a Comet can be continued *by* any *Law* of Mechanism. *By* some mechanical *Cause*, and *according* to some particular *Law*, it may perhaps be continued: But his Expression supposes, that the Law, *after* which any Motion is continued, is itself the *Cause* of its continuance. The word *Law*, in a physical sense, means nothing more than that degree or *proportion*, according to which some cause is observed to produce its proper Effect; as that of the Effect decreasing as the squares of the distances increase, is the Law according to which the cause of Gravity is observed to act. And though I may here seem to be criticizing on Words, yet whoever examines the affair of *Laws*, *Causes*, *Powers*, *Principles*, and *Qualities*, as they are set forth by some modern Philosophers of great name, will discover no small embarassment; of which I could give some curious Instances. The Truth is this; being ignorant of physical *Causes*, they have endeavoured to argue such Things out of the Creation, and have put these *Laws* into their place; which has produced a sort of equivocation, very unintelligible to those who are not apprized of it."

35. " If the Questions abovementioned were rightly put, there would be no such great difficulty in replying to them. Thus, if it be required, what mechanical *Cause*, is present in the

celestial Spaces, to continue the Motions of the Planets and Comets? Our Senses tell us, that *Light* is diffused throughout these Spaces; And we learn from several Experiments, particularly from those of *Electricity*, that the Matter of Light can *impel* and *resist*, and that with a degree of power hardly to be believed but by those who are witnesses of it. That the heavenly Bodies can move in Spaces filled with this matter, and yet feel no *resistance* from it, is not to be demonstrated by any physical proof."

36. "If it should also be enquired, after what *Law* of mechanism this *Cause* will act, the Answer is easy; there being but one Law known to us, which a fluid, issuing in strait Lines from a Center to a Circumference, can possibly observe; and it is this, that its force will decrease as the Angle grows wider; or to speak more strictly, its force will always be inversely as the square of the distance from the Center; And this is so well known to every Mathematician, that it is needless to insist upon it."

37. "Hence it will follow, that if the Rays of Light, or any other ætherial Matter, whether issuing *from* the Sun as from a Center, or pressing *toward* the Sun as toward a Center, have any share in the Motion of the Earth and Planets, the influence of such an Agent will be *reciprocally as the squares of the distances*: Its Power will increase and decrease according to the same Law, and for the same Reason too, that the quantity *of Illumination* does. This

Law

Law was firſt diſcovered by *Keplar*; and has been greatly advanced by the Labours of Sir *Iſaac Newton*. But then I beg the Reader to obſerve, it is, a geometrical Law; and as Geometry is not applicable to immaterial Eſſences, but only to *Matter* and *Quantity*, it muſt alſo be a Law of Matter, that is, a *mechanical* Law; and if the Planets are moved according to a *mechanical Law*, it muſt follow that they are moved *by* a *mechanical Agent*, be that Agent what it will. For it would be abſurd to the laſt degree, to believe that the action of an *immaterial Power*, or the immediate Influence of God himſelf ſhould be found to *decreaſe by a geometrical Rule*, and its force be capable of being *calculated* at various diſtances like the efflux of Light from a Candle."

38. "Should it likewiſe be aſked, what mechanical *Agent* is concern'd in the formation, growth, and ſupport of *Animals* and *Vegetables*? It is very clear from all Experiments, that in the common courſe of things, neither a Plant nor an Animal was ever yet formed or ſupported under the abſence either of *Air* or of *Heat*; by the latter of which, I would always be underſtood to mean, the *Effect of fire*. An Egg has *Air* incloſed at one end of it, to be expanded, and made to preſs upon the contents by the *Heat* of Incubation. And what is ſtill more remarkable, Air is found neceſſary, not to the *inſide* only, but alſo to the *outſide* of a ſhell, within which an Animal is to be formed; for

for Mr. *Boyle* obſerved, that the eggs of Silk-worms will not be hatch'd within an exhauſted Receiver, tho' it be expoſed to the Sun's Rays."

39. "With regard to *Plants*, every common Gardener could have informed Dr. *Clarke*, that Air and Fire have an abſolute dominion over the whole vegetable kingdom; the expence of Stoves, Thermometers, and Ventilators, might otherwiſe be ſpared, and the whole Buſineſs of Gardening tranſacted in a *Vacuum*. But this is ſo far from being the caſe, that it is really amazing to ſee, with what an exactneſs the ſeveral tribes of Plants agree in their ſubſtance, ſizes, and properties, with the *Seaſon* and *Climate* in which they appear, that is, with the different and unequal diſtributions of Heat and Cold all over the face of the Earth; of which Phænomenon, I ſhall have occaſion to take ſome farther notice in a proper place."

40. "As to the Body of a Man, the Circulation of the Blood, and the ſpontaneous Motion of the Limbs, if it can be ſhewn, that any of theſe Motions are carried on without *Breath* in the Lungs, and *heat* in the Veſſels, it will then be time enough to affirm, that they cannot obſerve a mechanical Law, or depend on the actions of a material Agent. So far as we are able to judge from what appears to us, the Circulation of the Blood, and all the animal Functions, are ſuſtained and carried on by an internal Heat, which keeps the Blood fluid, and by the exter-

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nal *Air* preffing into the Lungs. Thefe ferve as a Pump to draw the Blood from the Heart, and the Air keeps this Pump in Motion. Thus the Air is to the Body, what the weight is to a Clock; while the Heart, with its Valves, performs the Office of a *Pendulum*, to gauge and regulate the Circulation. What I have here faid in few Words, might be confirm'd at large from the Obfervations and Experiments of *Swammerdam*, *Bartholine*, Dr. *Hales*, and others.—— Were the Theory of *animal Motion* to be ftated for us, as that of the planetary Motions abovementioned, this Author fhould have fet us to account mechanically for the motions of a *living* Animal from the Example of a *dead* one; the Motion of the Planets, in *unrefifting Spaces*, being juft as unphilofophical, and as hard to account for, as the Circulation of the Blood in a dead Corps."

41. "I may obferve, upon the whole, that the way of reafoning Dr. *Clarke* hath chofen upon this occafion, can do no fervice to any Caufe whatfoever. His Defign is plainly this—— to throw fome difficulties in the way, and then lay the foundation of his own Philofophy in that *Ignorance* which is common to us all. For fuppofe we are not able fully to accomplifh the tafk he has impofed, and give fuch a mechanical Solution as fhall be adequate in every inftance; muft it be allowed, that there is no mechanical Agency, till we are able to explain particularly *how* every one of its Effects are brought to pafs? There

There may be in Nature a thouſand Examples of a mechanical Agency, where the particular *manner* of it hath not yet been diſcover'd, nor the Subject perhaps ever examin'd with ſuch a view. And in ſome caſes, I ſuppoſe, the Contrivance of an omniſcient Artiſt may, after all our labour, be above the reach of human obſervation; unleſs the mechanical ſkill of God and Man muſt neceſſarily have the ſame Limits."

42. "To build a Philoſophy on theſe caſes is to begin at the wrong end. The only courſe that can promiſe any tolerable ſucceſs, is to ſet out with the caſes that are well underſtood; and thence argue by analogy, to ſuch as are more remote, and difficult of acceſs. But to begin with the things that are unknown is the way to create difficulties where there were none before: And as we ſhall moſt probably try to make things of a piece, our ignorance *there* will diffuſe itſelf univerſally, and give a mixture of darkneſs to the Knowledge we had already obtained."

43. "Dr. *Clarke*'s manner of objecting doth alſo give me a fair opportunity of turning the tables upon him; and that, as I am inclined to think, very much to the diſcredit of all his reaſoning. For if it be true, that he who maintains the Mechaniſm of the Creation, is *obliged in Reaſon to be able to explain all* Effects in that way, and ſhew how *every thing* is performed mechanically; then it muſt be equally true that he who maintains the contrary, and rejects

the notion of a general Mechanifm, is obliged in Reafon to fhew, that *nothing* is performed mechanically. For if it can be fhewn, that mechanifm prevails in any one inftance, it will lead us to conclude, that it muft prevail in every other; upon a bare prefumption, that Nature has a wife Author at the head of it, and is govern'd by confiftent Laws, not by fuch as are capricious and contradictory. The Wifdom of God will be uniform in its Operations; and if it works with *natural means* in fome cafes, and we can be well affured of it, I may venture to fay, it does not work without them in any."

44. "To argue from the abfolute *Power* of God, exclufive of his *Wifdom*, and that he is *able* to act by the unmechanical forces of *Attraction*, *&c.* would but ill become thofe, whofe proper bufinefs it is to fhew how things *are* done, not how they *might* be done. Without doubt, it would have been poffible with God to have given Man the Senfe of *feeing*, on very different Principles from thofe at prefent eftablifhed. The *Power* of God wants not the mediation of Light, to convey to us a perception of diftant objects; but his *Wifdom* hath been pleafed to make ufe of this fluid medium, as the natural inftrument or phyfical caufe of vifion. The Eye is a compleat piece of optical machinery, perfectly analogous to a *camera obfcura*. The *chryftalline humour*, lodged near the protuberant part of it, is a double convex *Lens*, or magnifying glafs; the *Pupil* anfwers to the

hole in the Window-ſhutter; the *Iris* is a moveable Curtain, to enlarge or contract the pupil ſo as to admit a proper quantity of rays; it anſwers the ſame end as the *aperture* in a common Teleſcope; and the *retina*, which is an expanſion of the optic nerve upon the back part of the Eye, is the ſheet, upon which the images of the objects are properly coloured in miniature. What occaſion for all this *Apparatus*, when ſome quality with an hard name *might* have anſwered the end as well?"

45. "Is not this alone ſufficient to convince us, that the Wiſdom of God hath choſen to act with natural means; that is, with the inſtrumentality of a fluid medium, and matter properly arranged to receive its impreſſions? If this be done in *one* part of the Body, my reaſon will be ſuggeſting to me, it is done in *all*; that as the optic Nerves are acted upon by a material medium for the purpoſes of Viſion, ſo the *Lungs* muſt play, the *Heart* beat, the *Blood* circulate, and Life, Senſe, and Motion, be kept up throughout the whole human Frame, on the ſame plan of *Mechaniſm*."

46. "And if the Body of Man, which many Philoſophers have conſider'd as a leſſer World, be of a piece with the greater, as the ſame way of reaſoning, if carried forward, will incline us to ſuppoſe; the motion of that too is kept up by natural means. The ſame fluid medium that gives motion to the Lungs, or ſight to the Eye, may conduct a Planet in its orbit, and produce

all

all the various appearances that have fallen under the obſervation of the moſt induſtrious Naturaliſt. As there are no vacuums, no attractions, no repulſions in the human Frame, but all is carried on by the impreſſion of material forces, there is no reaſon to conclude that theſe imaginary principles (for ſuch I ſhall prove them to be) prevail in the planetary regions; but rather that all things are conducted by a like method even there alſo."

47. "The parallel now before us will ſerve to detect the weakneſs of that common argument againſt a plenum, and a mechanical agency, which is drawn from the doctrine of reſiſtance. Some learned Men are of opinion, that if the ſyſtem of the World were full of matter, a Planet muſt very ſoon loſe its motion. But this argument will make a very indifferent figure when applied to the human Body. There, I think, we have a plenum undiſputed; and the Blood, once in motion, is reſiſted by every Artery in the Body; the ſum total of which reſiſtance, as *Borelli* * has computed it, is almoſt incredible. He makes it equal to 180,000 lb. Yet this involuntary motion continues without any diminution of its velocity, till the Machine is quite worn out, or till the Providence of God is pleaſed to put a ſtop to it by ſome ſhorter method."

48. "Can any Man think he impoſes an

* De mot. Animal. P. II. Prop. 73.

unsurmountable difficulty upon God, because he can prove, that the fluids of the human Body, must meet with a resistance to their motion? Must the Frame of Man be turned into a vacuum upon this account? The fact itself is a sufficient answer to all such pretences. And if the Blood is not stopt in its Circulation by the resistance of the solids, why should the resistance of a fluid stop the Circulation of a Planet? for doubtless, if the divine Wisdom hath contrived a way to overcome this resistance, in one instance, it may in another; and the argument for a vacuum, deduced from the necessity for such a thing, will be very weak and inconsequential."

49. "To induce us wholly to give up the affair of mechanism, the Author of the papers against Mr. *Leibnitz* has added the following consideration. "That things (says he) could not be at first produced by mechanism is expressly allowed: And when this is once admitted, why after that so great concern should be shewn to exclude God's actual Government out of the world *&c.* I can no way conceive."

50. "We have an ambiguity here in the terms, which ought to be removed. For if by produced he means created, no sober Man, I suppose, will dispute that point with him; it being certain, that creation was no work of mechanism, but a pure act of the Will and Omnipotence of the Creator. If by production, he means that formation of terrestrial substances,

Plants,

Plants, and Animals, which was subsequent to the act of creation, it is certain that in that formation and disposition of God's works some material agents were employ'd, even the same that operate to this very day. The natural agency now in dispute, was the first article God thought proper to settle in the same disposition of the world: Air, light, and the firmament of Heaven, were first prepared and put into action: After that the formation of all other things followed in their proper place."

51. "If Dr. *Clarke* could have shewn, that Trees and Plants were made to grow before there was any Light or Air to be instrumental in the process, he had done something to the purpose: But as far as we can learn, his scheme of Philosophy agrees no better with the origin of nature, to which he here appeals, than with the present frame and constitution of it."

52. "As for excluding God's Government out of the World, if that was the design of Mr. *Leibnitz*, he must answer for it. But it can never follow, that if a second Cause be interposed, the first Cause is for that reason excluded: No Man would be so weak as to affirm that; because every second Cause, as such, must depend upon the first. The Author therefore has thought proper to call it an actual Government, which must mean either immediate, or real. If he maintains, that the agency of the divine Essence is immediate in the production of natural effects, which, in the judgment of some,

is the grand arcanum of the modern mathematical Philoſophy, it is incumbent upon him firſt to prove, that no ſecond Cauſe, created Eſſence, or material Agent is fitted for the purpoſe; which inſtead of being proved is hitherto taken for granted. If he means, that the real Government or Providence of God is excluded; neither will it follow, that his Government is leſs real, becauſe he rules the World by natural Cauſes under the directions of himſelf the ſupreme Cauſe. If this be a neceſſary conſequence, the Scripture itſelf is chargeable with it; and where it inſtructs us, that the Sun is made to rule over the day, it muſt inſinuate, that the Providence of God does not rule over the World."

53. "When we ſpeak of mechanical Cauſes as doing any thing in the World, Dr. *Clarke* will immediately take us up, and conclude they are to do it of themſelves, independent of the divine Power and Wiſdom; which opinion Mr. *Leibnitz*, with whom he was diſputing, had expreſſly diſclaimed. For my own part, I adhere only to the matter of fact; and that I know will bear me out againſt all the metaphyſical ſubtilties in the world. But if the Reader ſhould be diſtreſſed with any doubts in this matter, only let him remember that matter acts upon matter, not by an eſſential but a mechanical Power, i. e. by its motion: [illegible] in the natural, as in the moral world, [illegible] that there is no Power but of God.

is the grand arcanum of the modern mathematical Philoſophy, it is incumbent upon him firſt to prove, that no ſecond Cauſe, created Eſſence, or material Agent is fitted for the purpoſe; which inſtead of being proved is hitherto taken for granted. If he means, that the real Government or Providence of God is excluded; neither will it follow, that his Government is leſs real, becauſe he rules the World by natural Cauſes under the directions of himſelf the ſupreme Cauſe. If this be a neceſſary conſequence, the Scripture itſelf is chargeable with it; and where it inſtructs us, that the Sun is made to rule over the day, it muſt inſinuate, that the Providence of God does not rule over the World."

53. "When we ſpeak of mechanical Cauſes as doing any thing in the World, Dr. *Clarke* will immediately take us up, and conclude they are to do it of themſelves, independent of the divine Power and Wiſdom; which opinion Mr. *Leibnitz*, with whom he was diſputing, had expreſſly diſclaimed. For my own part, I adhere only to the matter of fact; and that I know will bear me out againſt all the metaphyſical ſubtilties in the world. But if the Reader ſhould be diſtreſſed with any doubts in this matter, only let him remember that matter acts upon matter, not by an eſſential but a mechanical Power, i. e. by its motion: For in the natural, as in the moral world, we hold that there is no Power but of God. If this di-

ſtinction

ſtinction be attended to, all that has been ſo induſtriouſly written in defence of immaterial impulſes in a metaphyſical way by the Author of the Enquiry into the Nature of the human Soul, falls to the ground without any particular confutation."

CHAP. IV. PART III.

SECTION 54.

Mr. Jones' *Animadverſions on the Doctrine of a* Vacuum, *and the* vis inertiæ *of Matter.*

"WE are now, ſays he, arrived at that part of the Subject, where all the admirers of *Demonſtration* will expect to ſee me drop; that is, to the Doctrine of a *Vacuum*, and the *Theory of Reſiſtances*, upon which it is founded. The learned Gentlemen, who object to the ſort of Philoſophy I am now recommending, know very well without being reminded of it, that if they have proceeded without evidence in this matter, their whole fabric falls to the ground without farther trouble; and if I cannot ſhew that they have, I am willing to own, that all I have yet ſaid, or ſhall hereafter ſay, muſt in their opinion go for nothing."

55. "Allowing then that there is a *Vacuum* or void ſpace in the World, their Argument is very ſhort, and will ſtand thus—— Bodies are obſerved to have motion in ſuch a ſpace; but that Motion cannot be the Effect of any material Cauſe, no ſuch Cauſe being preſent to them."

56. "Should we ſuppoſe this to be true, what a confuſed and heterogeneous mixture of ſolutions will it neceſſarily introduce into all our phyſical Diſcourſes? That God does in many Caſes govern the World by material Agents, and conſerve the Motions of Bodies by the activity of ſecondary Cauſes, is beyond diſpute. The ſupport of animal Life by *Breath*, the Motion of a Ship before the *Wind*, of the Sap in Vegetables at the approach of the Sun's Light, of the Mercury in a Barometer by the *preſſure of the Air*, of the Fluid in a Thermometer by the expanding Power of *Fire*, of Bodies impelled and driven off again by the Flux and Reflux of *electrical Æther*, with innumerable other Phænomena of Nature, all conſpire to eſtabliſh this plain Truth. And if it be an axiom in Phyſics, *that more Cauſes are not employed where fewer will ſuffice*, how comes it to paſs, that thoſe Agents which confeſſedly miniſter to ſo many and great Effects, are not ſufficient for the producing of all? Shall we allow, that God governs the World by a ſubordinate Agency and Mechaniſm in ſome Caſes, where that Agency appears to us; and deny it in others, merely

merely becauſe we have loſt ſight of it, or becauſe it would make againſt us? A Philoſophy that labours under this difficulty, and is one while working with a *material* Cauſe, and in the next Breath with an *immaterial* one, be it ever ſo ingeniouſly put together, will after all, be liable to this grand exception, that at beſt it is *inconſiſtent*, and unworthy of God. Every Body muſt ſee and know, that there are material Cauſes acting in the World; and he that denies it, muſt deny his Senſes. If theſe Cauſes are not ſufficient to perform *all* the Operations of Nature, then the Creator hath made uſe of ſuch means, as are not proportionable to the end. If the Creator himſelf performs them by the immediate Agency of his own Subſtance, then is there no need of any *other* Cauſes; they are all *ſuperfluous*. But that there are other Cauſes is abundantly evident; therefore they muſt be capable of anſwering their end, and every material Effect will be immediately owing to a material Cauſe. What I here ſay, is grounded on this reaſonable *Poſtulatum*, if it may not rather be called an *Axiom*, that the Wiſdom of God is *conſiſtent with itſelf* in its Operations; and that he wants neither Power nor Skill to avoid the error of inconſiſtency: Grant but this, and the Argument amounts to a *Demonſtration*. I muſt confeſs, it appears to me to be ſo unanſwerable that if I could not take off the pretended Evidence for a *Vacuum*, I ſhould nevertheleſs be ſatisfied, that it was a ſophiſm, and impute its

whole force to a want of ſkill in myſelf to lay open and detect the fallacy of it. And now let us proceed to give it a particular conſideration."

57. "I have a Manuſcript-paper by me from a learned and ingenious Gentleman of *Cambridge*, wherein the argument for a *Vacuum* is ſtated very cloſely; and he will not be offended with me, if I take the liberty of ſetting it down in his own words; for I know how to honour a Man of Parts and Diligence, tho we may happen to differ in ſome of our Sentiments."

58. "You will hardly (ſays he) deny the *vis inertiæ* of Matter, which Sir *Iſaac Newton*, and every Author but the *Materialiſts* think demonſtrably eſſential thereto, and proportionable to its quantity; and therefore, that it muſt hold equally in the moſt *ſubtile Æther*, as in the groſſeſt Matter. Hence it follows, from the *different degrees of reſiſtance* to Bodies moving in different Mediums, that equal Portions of different Mediums contain different degrees of *vis inertiæ*, and conſequently different *quantities of Matter*. But how can different quantities of Matter be contained in equal Bulks, without ſuppoſing *vacuities*, at leaſt in one of them? No *ſubtile Æther*, pervading the pores of the groſſer Medium, will ſolve the difficulty; becauſe ſuch an Æther muſt itſelf be *more porous* than the groſſer Medium, elſe thro' its *vis inertiæ* it would cauſe an *equal degree of reſiſtance*, contrary to fact and experience. Now what can this poroſity of the Æther be but *in-*

terſtitial

interſtitial vacuities? Muſt we invent another Æther to pervade the pores of the former, then another, and ſo on, till all the pores be filled? But this only drives us again upon the difficulty we have been endeavouring to ſhun; namely, that all Bodies are *equally denſe*, and ought *equally to reſiſt the Motion* of other Bodies thro' them. This, allowing the *vis inertiæ* of Matter to be eſſentially proportionable to its quantity, is a *ſtrict demonſtration* of an interſtitial *Vacuum:* And therefore difficulties ſtarted againſt it, tho' we could not ſolve them, ought not to move us."

59. " We are now poſſeſſed of the Objection in its full force. All Matter, from its *vis inertiæ*, or a natural indiſpoſition to change its place, muſt give a reſiſtance to Motion in proportion to its quantity: And as we find a different degree of reſiſtance to Bodies moving in different Mediums, there muſt be different quantities of Matter in equal Spaces; and conſequently there is juſt ſo much *more* of Vacuum, or abſence of Matter, in one of the ſpaces, as there is *leſs* of reſiſtance: Where there is *no reſiſtance*, there will be *no Matter:* So that we muſt either correct the modern doctrine of the *vis inertiæ*, or allow this to be, what Sir *Iſaac* himſelf hath called it —— *demonſtratio vacui*. As the *vis inertiæ* is a principle of ſo much conſequence, I am obliged to enter upon an experimental enquiry into the Nature of it; in the progreſs of which, I think it will appear, that ſuch an enquiry was

never made by Sir *Isaac* himself, nor by this ingenious Gentleman; who will find he has taken up with a Principle, which he never gave himself the trouble to examine. For after all that can be said, *Experiment* must be the test; and to that I shall appeal for the truth of what I am going to offer."

60. "We find then, that if a Body be at rest, a certain force is required to remove it out of its place; and this force is supposed to be necessary only on account of a *vis inertiæ* in the Body: For which reason, the force required must increase, as *the quantity of Matter* increases in the Body to be removed. All this will be true, if the *vis inertiæ* is true; but it is contrary to fact. Let us suppose this Body to be of a pound weight, and suspended by a line, so that on occasion it may vibrate as a Pendulum. If you would move this Body in a direction *upward*, the force required must be superior to a pound; if sideway in the segment of a Circle, of which the point of suspension is the Center, a much less force will do the Business; and this force being the true index of the *vis inertiæ*, if that be found to alter, though the *quantity of Matter* be still the *same*, it proves that the *vis inertiæ* is a changeable Thing, depending on some certain circumstances which must be taken into the Account. And it will appear, that if you can calculate the force which the action of gravity will have upon the Body, when elevated to any Angle, you will then know what

force

force is requisite to overcome its *vis inertiæ* or indisposition to Motion."

61. "If the same Body be taken in the Hand and left *at rest* in the Air, no force at all is requir'd to put it in Motion *downward*; for the cause of gravity immediately sets it a going in its proper direction. So that, *cæteris paribus*, the *vis inertiæ* in all Bodies, being more or less, just as you concur with or contradict the action of Gravity upon them, seems *in fact* to be no other than a consequence of their Gravity. When we attempt to give a motion to a Body different from that of Gravity, we find it already pre-engaged by a determination toward the Earth's Center: And this natural force is making its effort every moment against any foreign force that can be applied to it; to which it is owing, that projectiles, instead of proceeding in a strait line, describe a parabolic Curve. If Gravity and the *vis inertiæ* were things essentially different, and independent of one another, *each of them* must occasion a resistance proportionable to the quantity of Matter; and the *whole* resistance, as discoverable by Experiment, would be the *Sum* of two different resistances, the one proceeding from the Cause of gravity, the other from the *vis inertiæ*. But I am fully persuaded, that in all entire or detached Bodies, we shall discover no resistance to a change of place, but just so much as ought to proceed from the action of gravity upon them, and no more."

62. "If this be true, if the *vis inertiæ* be only

only the consequence of another Principle, two corollaries will arise, sufficient to dispatch all the argumentative part of the above demonstration. For then it will follow, that if we can alter the state of a Body in respect of its gravity, or its natural tendency *downward*, we shall, at the same time, alter its state in respect of its *vis inertiæ*, or natural indisposition to move when left at rest: The Truth of which will appear from an easy Experiment."

63. "Take a light glass Bubble, and load it inwardly with Mercury or any other heavy substance, till it is precisely of the same specific gravity with water. This done, we will suppose it to weigh two ounces. Let it now be suspended by an hair to the arm of a ballance, and laid at rest upon a Table: If you would raise it from thence, and give it a motion upward, you must charge the other end with a weight some small matter above two ounces; which may stand for the force requisite to overcome its *vis inertiæ*. Let the Body then be placed near the bottom of a Vessel filled with water; in which position it will remain at rest: But if you would now give it motion in the same direction as before, it may be done with a single grain, that is, with only one thousandth part of the force required in the former case. The reason of this seeming Paradox is this; the Motion given does really coincide with that of Gravity, tho in appearance it contradicts it. For the Body being of equal weight with an

equal

equal bulk of water, when the Body has moved out of the ſpace it occupied at reſt, an equal bulk of water, thro' the action of Gravity upon it, has deſcended into that ſpace; and if we put 1000 for the force neceſſary to raiſe the Body, and 1000 for the force of the ſubſiding water, the difference between theſe two, leave a remainder for the *vis inertiæ* = 0. Some quantity however indefinitely ſmall muſt be allow'd to produce an *inequality* between the Body and the Water; for where all things are equal, no motion can enſue, But how much the *vis inertiæ* has to do in this Experiment, I leave to be determined by better judges, when they have conſider'd it. It may likewiſe be added, that after the Bubble has been moved by a force equal only to a *ſingle grain*, thro' a ſpace of water equal to itſelf, *twice as much Matter has been put in motion* thereby, as would have been moved in a Vacuum by a force ſomewhat ſuperior to *two ounces*, becauſe the bubble has diſplaced a quantity of water equal in weight to itſelf; and Water *reſiſts* a moving Body nearly a thouſand times more than Air. But how can all this be poſſible, if an *indiſpoſition to Motion be eſſentially proportionable to the quantity of Matter?*"

64. " My ſecond corollary applies itſelf directly to the demonſtration. As the *vis inertiæ* is a neceſſary conſequence of gravity, if there be any Fluid, be what it will, which acts as the *Cauſe* of gravity, that Fluid muſt itſelf be void of gravity *conſidered as an Effect*, and conſequently

quently of that resistance which has been ascribed to the *vis inertiæ*. To say then, that the *vis inertiæ must hold equally in the most subtile Æther as in the grossest Matter*, and that from the different Degrees of weight or resistance, *different quantities of Matter are contained in equal spaces*, is to beg the Question, that Gravity has no material Cause. But it would be unfair, to demonstrate that it has none, merely by attributing to it such a property, as from its Nature and Office it cannot possibly have."

65. "It is incumbent therefore on all those, who would build a Philosophy on the *vis inertiæ*, first to shew us what it is, and to prove by some Experiment, that there really is such an *original* Principle in Matter, to be discovered *apart*, and *independent* of every other Principle at present established in Nature, before they can raise from it one single conjecture, much less a demonstration. I say, of *every* other Principle; for a resistance to Motion may be occasioned by more Principles than one. A Mass of Iron or Stone, first examined with respect to the Principle of *Gravity*, then to that of *Cohesion*, or the Application of its constituent Parts to one another, will teach us, that the *whole* quantity may be put in Motion with respect to the Earth's Center, much more easily than *half* the quantity can be moved with respect to the other half: So that if the force with which some solid Bodies cohere, were to take place in Matter, as universally as gravity now does;

does; we might compute the *vis inertiæ* to be ten thouſand times as great as it is, becauſe we ſhould oppoſe the coheſion of Bodies, where we now oppoſe their gravity."

66. "Were all Matter at reſt, and the action of the Elements made to ceaſe, ſo that not a ſingle particle of matter ſhould have any determination to one ſort of motion rather than to another, that would be the time to make an Experiment on the *vis inertiæ*. But this Principle, ſo far as it is ſubjected to examination under the preſent œconomy of the world, is a thing unfixed and conſequential, not uniform and independent, as the Mathematicians have ſuppoſed; whoſe greateſt misfortune it hath been, not to conſider things *as they are*, but to feign an arbitrary and abſtracted ſtate of Matter, and thence to argue upon it in its dependent ſtate; when they are really more different, than the ore of a metal depoſited in the Earth, from the ſame metal formed into the wheels of a Clock. And what is much more offenſive, the ſame Philoſophy which has given to Matter an *indifference* to motion by the *vis inertiæ*, has alſo given it an *inclination* to motion by the virtue of *Attraction*; both of them *inherent* (as ſhall be hereafter ſhewn) in the ſame particles. The former of theſe does indeed ſeem oppoſite to *materialiſm*; but the latter has ſo ſtrong a reliſh of it, that a Friend to the Principles of *Spinoza*, hath blended them both together *. And even Dr.

* See the *Phyſical* Paragraphs, in a Piece entitled, an *Eſſay on Spirit*.

Derham, an undiſguiſed and well-deſigning Author, has granted as much as *Epicurus* himſelf would have required of him. It was his opinion, that in *the firſt production of Matter*, the great Author *of all Things* INSPIRITED the materials *of which the World conſiſts with ſuch an* active quality, *as ſerves to preſerve the Globes entire, and enables them to revolve about their Centers* *. If this Paſſage does not allow to Matter, a power of directing itſelf, and conſerving its own motions, I know not what to make of it. But it is no concern of mine, ſo I return to the argument; leaving it to thoſe who pretend to have renounced *materaliſm*, to reconcile their own conjunct doctrines of *inert Matter*, and *inſpirited Materials!*"

67. Now if all this be true, and Mr. *Jones'* Reaſoning cannot fairly be ſet aſide, the preſent Philoſophy muſt be allow'd to reſt on a very incomplete foundation, and, when ſtrictly examin'd, will be found not as yet to have reach'd the ſummit of perfection; and if ſo, will it not be the moſt egregious folly to neglect the cultivation of ſo remarkable and ſurpriſing a Diſcovery of a ſubtile elaſtic Medium; a Medium which had been hitherto denied, and yet without which the operations of Nature cannot be ſatisfactorily accounted for? If his aſſertions are falſe, how comes it to paſs that they have never been anſwer'd and refuted in the ſpace of four

* Aſtro-theol. p. 148.

years,

years, nothwithſtanding he ſeems earneſtly to deſire that his Reaſonings may be examined? His words are "If there be a conſiderable defect in any of my deductions, I ſhall be very glad to be better informed; and perhaps ſome of the followers of Sir *Iſaac Newton* may ſhew ſo much candour and humility toward a Man, who means well, as not to think him too inſignificant to be taken notice of."

CHAP. V. PART III.

SECTION 68.

The Doctrine of Reſiſtances *conſidered, and other Arguments for a* Vacuum *examined and* refuted.

THE Quotations from Mr. *Jones*' Eſſay, contained in the foregoing Chapter, may ſuffice to ſhew, "That the celebrated demonſtration of a *Vacuum* has *ſet out* wrong. It will, continues he, be as eaſy to prove, even waving all that has been ſaid on the *vis inertiæ*, that it has *concluded* wrong; if the *relation between a moving Body and a reſiſting Medium* be rightly underſtood."

69. "*When a Pendulum is made to ſwing in Air, Water*, or *Mercury*, the reſiſtance it meets with is greater, *as the medium is denſer: And as a plenum of Æther, ſuch as the mechanical Phi-*

losophy requires, would be more dense than any other Fluid, its resistance, they say, must be greater: No Motion could possibly continue in it. But then as motion is observed* to continue in the heavens, without any *sensible diminution*, there can be no resistance in the heavenly *spaces, and consequently no matter of sufficient density to occasion it.*"

70. "This was Sir *Isaac Newton*'s way of computing resistances, and the use he made of them when computed. That we may see whether this doctrine agrees with Experience, Let us suppose a Ship, with its Sails spread, to be in motion before the Wind: Every Body must allow me, that if the Wind were to keep its direction, and the Ship to have an open sea, it would go quite round the globe; and for the same reason that it makes one revolution, it would make another, and so on *ad infinitum*. Are we to say, that the Air, in which it moves, is an *unresisting Medium*? We ought to say this, if the demonstration abovementioned really is what it pretends to be. But the truth is, a Medium may, *in its Nature*, be a resisting one, and yet *in fact* give no such resistance, as shall be any impediment to a Body moving in it. For let any Person tell me, how much resist-

* Is not here a palpable mistake which ought to be clear'd up? — Does not Sir Isaac *Newton* affirm that Æther is exceedingly more rare than Air, and do not electrical Experiments prove it to be vastly more so? Why then is it here supposed more dense than any other fluid?

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ance the Ship receives from the Air in this case? The answer must be,—— less than none: The resistance here is a negative quantity; and the Ship is so far from *losing* its motion that it is continually *receiving* it, as it passes through the Air; yet it would be false to affirm of Air in general, that it is not a resisting Medium. As to the *Water* the Ship sails upon, this being not the *cause* of its motion, will serve to retard it; but as the continued impulse of the Air behind, is superior to the sum of all the following resistances, *first*, of the *Air before*; *secondly*, of the *Water* the Ship sails upon; and *thirdly*, of the *cause of gravity* which is continually acting upon it; the motion will continue notwithstanding these impediments."

71. "Were it to be laid down as a general rule from this particular instance, that *Water* resists motion, but *Air* does not; neither will this coincide with Experience. A cork, or any other light body, thrown upon the stream of a sluice or floodgate, will be carried off with it; and as it is common for a considerable part of the water to return again upon the stream in a curve, if it be obstructed by the banks, and have but a narrow out let, the cork may come about with it, and compleat its revolutions, so long as the cause continues to act upon it. The water gives no more resistance in this case, than the air did in the other: And thus it will happen universally, that every fluid, where it is the *cause of motion*, will not be found in that case to

to give any *resistance*, be its quantity of matter great or small."

72. "We are now prepared to return to the Pendulum; if it vibrates in *Air*, the air will retard its motion; and there is a good reason why it should do so, for air is not the *cause* of its motion. If in *Water*, neither is that the cause of its motion: And it will give a greater resistance to it in proportion to its quantity of matter, that is, in proportion to the action of gravity upon it. If in *Quicksilver*, it will meet with a still greater resistance, for the same reasons. But if there be any elementary Æther, acting as the natural *cause of gravity* in Bodies; it is just as absurd, to search for the resistance of *such a fluid*, from the motion of a *falling Body*; as for that of the *Air*, from the motion of a Ship that sails by it; or for that of *Water*, from the motion of bodies carried down by a current of it. If one Philosopher may conclude, that gravity cannot be owing to any particular material fluid, because he has found, that this fluid does not *resist* a *gravitating Body*; may not another demonstrate with equal truth, that a Ship cannot sail by the action of the air upon it, because he finds, from the nicest observations, that the air does not *deprive* it of its motion?"

73. "Whether the learned will consider of these things, I cannot pretend to judge; in time perhaps they may: But for a while, I presume, he that ventures to interpose, must be content to let the reproach fall upon himself.

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There was a time when Men had given up their Underftandings to the logic of the Schools*

* "I will give a fpecimen of their *manner* pertinent to the Subject we are upon. It is a *logical demonftration of a vacuum*, extracted, from *Lib.* 4. c. 6. of *Ariftotle's* Phyfics. *If there be no* vacuum, *there can be no* loco-motion. *For a fpace already full cannot receive any thing into it; if it did, there would be two Bodies in the fame place; which is an abfurdity.* Some of his Commentators put it thus. — probatur affumptio; quia corpus quod locum mutat, vel inani fpatio excipitur, vel pleno: Si inani, habetur propofitum: Si pleno, fequitur duo corpora fefe permeare — "*The affumption is thus proved; becaufe a body that changes its place, is received either into a fpace* full *of Matter or into one that* is empty: *If into an empty fpace, the point is proved; if into a full fpace, then it follows that two Bodies muft penetrate one another's dimenfions.*" And *Ariftotle* tells us of one *Meliffus*, an antient Sophift, who being reduced to the laft extremity by the force of this [miferable] argument and determined not to admit a *vacuum*, denied the reality of Motion, and held the univerfe to be immoveable. Had this Philofopher trufted to experiments inftead of logic, he might have filenced his adverfaries with very little trouble. For if a bullet be put into a bottle, quite full of water, and clofe ftopt down, we have a fpace filled with an *incompreffible fluid*; which conftitutes as good a plenum as need be defired; yet upon inverting the bottle, we find the bullet can move from the top to the bottom, or from one fide to the other, almoft as freely as if the bottle were empty. Does it move into an empty fpace, or into a full one? Why truly,

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and the quirks of *Aristotle*; and woe was to the Man, who dared to publish a suspicion against them. That fashion is now exploded; and we are all enslaved to the pretences of a *mathematic* certainty. But if the doctrine of a Vacuum is really weak and without foundation, this fashion will have its period like the former, and we shall be restored again to the enjoyment of our philosophical rights and liberties."

74. "It appears then, that the *vis inertiæ* of matter, under the present constitution of natural things, is no fit principle for a Philosopher to begin with; and that even supposing such a principle, I say, supposing such a principle, yet to argue from that to *physical causes* is an absurdity: For when any fluid matter becomes a *cause of motion*, the case is quite altered; and its *resistance*, be it ever so great in *other cases*, will be of no account in *this*. The Gentlemen who have reasoned from this principle, have never once attempted to inquire, what will be the case, where matter gives *motion* to other matter; but taking it for granted, that the great Author of Nature has created a set of Elements, for no single purpose, but to obstruct bodies in motion, have drawn themselves into the palpable absurdity of proving by a mathematical demonstration, that a matter of fact is

into neither; for the bullet and the fluid *change places* with one another, so that the motion is not hindred, though the space is always full of matter."

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an impoſſibility. Of which, if any doubt ſhould yet remain, I will ſubjoin the following Experiment, with a few ſhort reflexions upon it."

75. "At the extremities of a ſteel Rod of two feet in length, let two Lamps of thin glaſs of a ſpherical figure (or any other that the Operator chuſes) be ſuſpended, as in Pl. III. fig. 1. Over theſe Lamps let there be two Vanes of Plate-braſs placed with contrary aſpects, and inclined to about half a right angle. The Rod thus furniſhed is to be poiſed by means of a cap fixed to the middle of it, on the point of a needle, ſupported by a foot and pillar. As ſoon as the Lamps are lighted, the machine will begin to turn upon its center, making ſeveral revolutions in a minute, and will continue thus to move, ſo long as the lights continue burning: And ſuppoſing the lights to have a perpetual ſupply, the conſequence of that would be a *perpetual motion* in the Machine."

76. "We will imagine a mathematical Philoſopher to be contemplating this ſight at a diſtance. If his Eye is in the plane of the motion, the lights will appear to move backward and forward in a ſtrait line: But as their velocity will be apparently unequal in different parts of the line, he will conclude they move in a curve; and by conſidering attentively in what proportion the apparent motion is accelerated and retarded, he will diſcover that curve to be a perfect Circle. Thus far he argues as an *Aſtronomer* and

Geometrician; therefore his conclusion will be undeniable: And I mention this to shew the distinction between *Astronomy* and *Physics*. But in the next place, he proceeds to investigate the *Causes* of this Motion: And having found, as he imagines, that all matter must *resist* motion in proportion to its quantity; if the lights circulate in a *resisting Medium*, their velocity he concludes must be diminished, and by degrees be utterly lost. But having observed for several days, and he might do it for as many hundred years, that they continue to move with the same velocity, and compleat their periods exactly in the same time, as when he first began to make his observations; he concludes, they must move in an *unresisting space**: And having dispatched all *material impulses* out of the way, assigns a *projectile* force as the cause of their *progressive* motion, and an *attractive* force, exactly counter-balanced to it, (that is, equal to the *versed sine* of an arch described in a given time) as the cause of their *circular* motion: Affirming at the same time, that these two forces are sufficient to account for all the Phænomena, and will do it *better than any material Me-*

* "Against filling the heavens with fluid mediums, unless they be exceeding rare, a great objection arises from the regular and very lasting motions of the Planets and Comets—thence it is manifest, that the heavens are void of all sensible resistance, and by consequence of all sensible matter." *Opt.* Q. 28.

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dium whatſoever *; and that in the whole courſe of this reaſoning, he has not *made one ſuppoſition* †. The ſum of this evidence is given us in a few words by that ſkilful Mathematician Dr. *Cotes*, in his Preface to the *Principia*: *Corpora progrediendo motum ſuum fluido ambienti communicant; communicando amittunt; amittendo retardantur.*——" Bodies in their progreſſion communicate their motion to the ſurrounding fluid; what they *communicate* they loſe; and by loſing it they are retarded."

77. " Then he undertakes to prove, that motion cannot be kept up by the impulſe of any fluid whatſoever, but upon the following condition——*Niſi velocitas abſoluta fluidi recurrentis duplo major fuerit quam velocitas abſoluta fluidi propulſi; quod fieri nequit*——That is, " unleſs the abſolute velocity of the fluid which " falls in *behind*, be twice as great as the abſolute velocity of the fluid driven away *before*; which cannot poſſibly be ‡." We have in theſe words the whole ſtrength of the *Newtonian Hypotheſis*; this is its fundamental argument; yet if it be compared with the preſent Experiment, there is not one word in it, from the beginning to the end, that will hold true.

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* " The motion of the planets and comets being better explained without it." Q. 28. † " Hypotheſes non fingo" *Princip.* ad *fin.* ‡ " This, by the way, will prove, that when a cork ſwims down a ſtream, the water muſt run twice as faſt behind as it does before it."

For, in the first place, these two bodies cannot, in Dr. *Cotes'* Sense, *communicate their motion* to the surrounding fluid, because they were left *at rest*, and had *none to communicate*. They are no *projectiles*: And the mathematical Philosophy having made *projection* its first Principle of motion, is entirely to seek, where *that* is out of the question. Secondly, as they communicated no motion, they *lose* none; but are continually receiving a fresh and equable supply of it; for which reason, thirdly, they are not *retarded*; but are possessed of a motion, which, in theory, is absolutely a *perpetual* one. Whence it appears, fourthly, that the *fieri nequit*, to which Dr. *Cotes* hath reduced himself, hath affirmed too much, and confuted itself. For if the *pressure* of the surrounding fluid be greater on the illuminated side of the Vanes, than its resistance on the opposite sides; that *inequality of pressure* will necessarily produce a motion toward the weaker side; and for the same reason that it produces, it would also conserve the motion for ever.——Fifthly and lastly, the well-known inference from a *continuance of motion* is worst of all; for if the machine were placed in a *vacuum*, that is, in a space void of *Air*, the lights would expire, and *motion* be at an end. A small hint will be sufficient here by way of application; only let it be remember'd, that the lights we use for experiment-sake, will decay in spite of us; whereas that Lamp, which God hath lighted up in the world, never goes out.

out. And he that can retain so mean an opinion of the *Sun*, that *marvellous Instrument* of the divine Wisdom, as to suppose it acts, not by the emanation of its *light*, but by its *quantity of solid matter*, should *put out* the two Lamps and *weigh* them, in order to account for this Experiment. If this is not enough to convince the ingenuous part of our Mathematicians, that their Science hath been misapplied, and that their way of reasoning upon *physical causes* is fundamentally wrong; they must be left to philosophize *suo more*: If they are deaf to the evidence of *Nature*, it is hardly to be expected they will yield to any remonstrances of mine."

78. "As the doctrine of a *vacuum*, and the *theory of resistances*, are points of so much importance, I have tried to be as particular as the cause required, and as methodical and perspicuous as my small abilities would allow me." The Conclusion of this Paragraph is of so modest and pertinent a nature, that I should, by no means, have omitted it here, had I not before given it my Reader at the end of the very last Chapter.

79. "Experiment and Logic having both failed in the Demonstration of a Vacuum; let us see what stress is to be laid on *Geometry* in the case before us: For we have been so stunned of late years with its praises, that it will be neither prudent nor handsome to overlook its pretensions. Dr *Keil* the astronomical Professor was a very eminent Geometrician, and as strenu-

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ous an advocate in behalf of a Vacuum. To convince us that there really is ſuch a thing in nature, he offers the following demonſtration, which I fix upon, becauſe it has the Author's own commendation, who calls it an *invincible* one, as the Reader will find in the 17th page of his *Philoſophical Lectures*. He deſires us to "ſuppoſe all the matter in the univerſe to be "amaſſed into two ſpheres, which may be re-"preſented by two circles, whoſe centers are "A and B. If theſe ſpheres touch one another, "it is neceſſary that they touch one another "in one point only, by the elements of Geo-"metry—— And therefore there will be be-"twixt the other points of theſe ſpheres a cer-"tain and determinate ſpace not replete with "matter. Hence the Author concludes, "That "there is *in reality a ſpace* diſtinct from all "Body." p. 19.

80. "This is Dr. *Keil*'s *invincible* Demonſtration; for the erecting of which, you are only to allow this ſmall ſuppoſition, that the Omnipotence of God might poſſibly accumulate all the matter of the univerſe into two ſolid ſpheres; and becauſe there *would be* in this caſe a ſpace void of all matter; it follows in his way of reaſoning, that there *really* is ſuch a ſpace. This Author ſeems to have been ſo full of Geometry, that there was no room for any Logic; elſe he might have picked up enough of it at Oxford to have taught him —— *a poſſe ad eſſe non valet conſequentia*. Beſides it is the proper Buſineſs of a

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Philoſopher to conſider the operations of nature, as nature is now conſtructed; where I apprehend, he will find work enough without making a new world, or ſhuffling the old one into a new ſhape. But Dr. *Keil* imagined it would edify us more, to tell us what ſtrange things would happen, if the world were all taken to pieces, and put together again in ſuch a form, as could anſwer no one purpoſe of the Creation."

81. "If a queſtion had been put to him, whether the motion of a *Pendulum* in a Clock is preſerved by the action of occult virtues propagated through void ſpaces from one wheel to another, or by a contact and bearing of the parts upon one another from the weight to the pendulum; he might have demonſtrated the former *invincibly*, by ſuppoſing, that if the matter of the whole machine were melted down, and made up again into a couple of wheels, their circumferences could touch one another but in a ſingle point; and a Man might make a Clock upon this principle, with juſt as much accuracy as he can philoſophize upon the other. He that will impartially conſider this, and many other geometrical arguments of the ſame complexion (with which I could fill a Book if it were neceſſary) will not be very haſty to believe any propoſition, becauſe it is *ſaid* to be ſupported by mathematical evidence; which tho' it be ſtrong in its proper place, and undeniable if conſidered in the abſtract, is nevertheleſs, when miſapplied,

just as weak as any other sort of evidence that is equally impertinent. The lovers of mathematical learning, like other Men, are too fond of magnifying their favourite Science; and will be introducing it, where it can add no light, but will spread an air of mystery and darkness over a subject, in itself plain and intelligible enough. Such unseasonable applications of it are so far from advancing its credit with sober Men, that they are in danger of bringing a pleasant and profitable branch of learning into contempt."

82. "It was an observation of the excellent Lord *Bacon* whose judgment in these matters hath never yet been called in question——*optimè cedit inquisitio naturalis, quando physicum terminatur in mathematico*——* "Every natural disquisition is brought to its proper issue, "when a physical principle terminates in a "mathematical operation." The reverse of this is the practice of Dr. *Keil*: He perceives that a thing will hold true in the *mathematics*, and then turns the world upside down to make his *physics* agree with it. If that be the best Philosophy, which goes from physics to the mathematics; that must needs be the worst, which goes headlong to the mathematics before it is ready for them, and canonizes a blunder by a demonstration. So that Dr. *Keil* was rather too severe in censuring so unmercifully, and laying such an heap of hard names upon his Adversaries,

* Nov. Org. L. II.

ries, "whose errors," he says, "spring from "hence, that Men ignorant of Geometry will "presume to philosophize, and give the causes "of natural things." For be it ever so true, that some Philosophers have not been Geometricians; he hath shewn it to be equally true, that every Geometrician is not a Philosopher."
—— Mr. *Jones* concludes this part with the following observation: "A Mathematician whose Judgement hath not been infected knows very well that Geometry can as soon *create* a system of Politics as a system of Physics. He knows, that in every physical operation, he must have *physical data* to begin with; and that if he is wrong *there*, all the geometrical skill upon earth will never set him right; but rather lead himself and others into the danger of perpetuating the mistake, by calling the work a *Demonstration.*"

CHAP. VI. PART III.

SECTION 83.

Animadversions on Mr. Barrow's *Account of* Æther.

THE Compiler of a late Universal English Dictionary, in Two Volumes *Folio*, having advanced some Positions on Æther, which appear to have no proper Foundation in Truth, the Author of this

Work thinks it incumbent upon him to make a few Remarks thereon in the Chapter now in hand.—— " Æther, [αἰθὴρ from αἴθω to burn, becauſe ſome of the Ancients ſuppoſed it to be of the Nature of Fire,] in Philoſophy, ſays Mr. *Barrow*, is a very thin, elaſtic Fluid, readily pervading the pores of all Bodies, and by its Elaſticity expanded thro' all the Heavens."

84. " As this Æther is only hypothetical, it is no wonder that Philoſophers ſhould differ with regard to its Nature and Properties; ſome will have it of an elementary Nature, and diſtinguiſhed from other Bodies only by its tenuity, *&c.* whilſt others look upon it as another Species, and not elementary; but rather a ſort of fifth Element, of a pure, more refined, and ſpirituous Nature, than the ſubſtances about our Earth, and void of the common affections thereof, as Gravity, *&c.*"

85. " It is ſurpriſing to obſerve how very fond ſome Philoſophers are of this ſubtile Æther; one accounts for the cauſe of Gravity thereby, another for muſcular Motion, a third for Electricity, a fourth derives animal Spirits from it, and a fifth elementary Fire: In ſhort, we want nothing but the proof of ſuch an Æther to account for almoſt every Thing by it. But is it not a prepoſterous method of proceeding to account for any Thing by a Principle in itſelf unaccountable, and utterly unknown?"

86. " But, ſuppoſe the exiſtence of this Æther could be proved, we ſhould ſtill be at a

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lofs to account for the material caufe of this prodigious elaftic Power in the particles of it; we fhould indeed advance three or four fteps higher on the infinite Ladder, but fhould be equally non-plus'd with the mechanical caufe of Elafticity then, as we are at prefent with Gravity."

87. "Befides, it is evident by Experiments, that this Power which actuates Bodies, whatever it be, is not either folely attractive or repulfive; but produces both the different effects in different circumftances and diftances. Thus the Magnet at one diftance, moves the Needle towards itfelf; at another diftance, it caufes it to recede, or move the contrary way. This Power in Iron is attractive, if touched on the Magnet in one direction; but if in a contrary, it becomes repulfive. The fame ambiguous properties of this Power obtain in Electricity, and undoubtedly in all other kinds of attractions. Therefore, before we endeavour to find out a Power, Spirit, or Æther, that fhall move Bodies either by attraction or repulfion, it is previoufly neceffary to difcover an Agent that fhall do both; for fuch a Principle is, at prefent, the *Defideratum* to our further advances in the refearch of natural caufes."

88. "Æther, in Chemiftry, is an extremely light and penetrating Fluid, made of Spirit of Wine deprived of its phlegm by diftillation with oil of vitriol, and then precipitating the fulphureous Gas with an alcali." —— The Reader

may see the whole process for making this ætherial Fluid, in the Philos. Transf. No. 461,

89. "This ætherial spirit, is one of the most noble, and useful menstruums in all Chemistry; for all essences, and essential oils are extracted by it immediately, without the mediation of Fire, from woods, barks, roots, herbs, flowers, berries, seeds, &c. Thus, from castor may be extracted an oil, sweeter than that of cinnamon; also the true oil of saffron, &c. For if you pour on the ingredient, in a proper vessel, a spoonful or two of the æthereal liquor, and after it has stood an hour in a cold place, fill up the vessel with cold water, you will see the essential oil swimming upon the water, which may be easily separated by the funnel. Of this essential Oil, one drop only upon a lump of sugar manifests to the taste, &c. the medicinal virtues of the plant, exquisitely drawn out, comprehended in this essence. In like manner the essential oils of exotics are easily extracted.——It is not however, a true essential oil, but an excessive strong tincture, or essence."

Remarks on Mr *Barrow*'s Account of *Æther*.

90. *Barrow.* "Æther, &c. because some of the Ancients supposed it to be of the Nature of Fire"——

Remark. The Ancients imagined there existed a more fine and subtile ætherial Fluid than the common Air, and that they discover'd it to be

be of the Nature of Fire; Bishop *Berkeley* was of that opinion, and we find it now verified by the electrical Fluid, which appears, not only to be a more pure elastic Air, but also a most powerful Fire.

91. *Bar*. " Readily pervading the pores of all Bodies " ——

Rem. This seems true only in part, for tho' such a subtile fluid appears, from electrical Experiments, to exist in all gross Bodies, yet, not so as readily to pervade all with the same freedom: The Bodies term'd non-electrics, are those only which it may be said readily to pervade.——In Bodies term'd Electrics it appears most firmly fixed, or (to use Dr. *Franklin's* expression) they retain it strongly and obstinately; consequently as that cannot be moved out, so the electrical Air (being the same) cannot readily pervade them in the manner it does non-electrics, on account of the mutual repelling property of the particles of each, *viz*. those of the electrical Fluid, and those fixed in the gross Body; whereas in the pores of Bodies of the former kind, it stands loose and free, and on particular occasions moves as freely thro' them and out of them, in any kind of direction.

92. *B*. " And by its Elasticity, is expanded thro all the Heavens " ——

R. Must not such Universality be allow'd to be the natural consequence of a fluid so extremely elastic and subtile?

93. *B*. " As this Æther is only hypotheti-

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cal, it is in no wonder that Philoſophers ſhould differ with regard to its Nature and Properties." ———

R. That ſuch an Æther or pure Air was indeed formerly hypothetical only, cannot be denied, and therefore no wonder (as Mr. *Barrow* obſerves) if different Philoſophers ſhould have form'd different Sentiments, with regard to its Nature and Properties; yet, as an elaſtic Air is now diſcover'd to exiſt in groſs Bodies, much more ſubtile than common Air, and conſentaneous and agreeable to Sir *Iſaac Newton*'s Æther, it is preſum'd, there cannot be ſtill the ſame reaſon for ſuch diverſity of opinions, concerning either its exiſtence, or its *Nature* and *Properties*, as before.

94. *B.* "It is ſurpriſing to obſerve how very fond ſome Philoſophers are of this ſubtile Æther; one accounts for the cauſe of Gravity thereby, another for muſcular Motion, a third for Electricity" ———

R. Had the Author ſpoken out, he would have ſaid plainly, it is ſurpriſing to obſerve, how very fond Sir *Iſaac Newton* is of this ſubtile Æther, who, in his *Principia*, accounts for muſcular Motion, for Electricity, and other Things by it; and, in his Optics, even for Gravity itſelf by means of this univerſal Æther, which, he ſeems to think, is expanded through all the Heavens. In ſhort, he wanted nothing but the proof of it, to account for almoſt every Thing by it.

95.

95. *B.* "But is it not a prepoſterous method of proceeding to account for any thing by a Principle, which is in itſelf unaccountable, and utterly unknown?" ——

R. Sir *Iſaac* himſelf ingenuouſly owns, that tho' he adopts it as his Opinion, yet he was not fully ſatisfied about the Laws by which it operates, *&c.* See his own Words, Part I. Section 75. and verified, Sect. 76. 77. *&c.*

96. *B.* "But ſuppoſe the exiſtence of this Æther could be proved, we ſhould ſtill be at a loſs to account for the material Cauſe of this prodigious elaſtic Power in the particles of it; we ſhould indeed advance three or four ſteps higher on the infinite ladder, but ſhould be equally *non-plus'd* with the mechanical Cauſe of Elaſticity then, as we are at preſent with Gravity."—

R. We ſhould be juſt as much at a loſs to account for the material Cauſe of the ſurpriſing elaſtic Power of the Æther then, as we are now to account for the material Cauſe of the elaſtic Power of the common Air, and no more; and ſhould be juſt as much *non-plus'd* with the mechanical Cauſe of the one, as we are for the ſame Cauſe of the other.

97. *B.* "Beſides, the Power which actuates Bodies, whatever it be, is not ſolely attractive, or ſolely repulſive, but produces both the different effects in different circumſtances and diſtances. Thus the Magnet at one diſtance, moves the Needle towards itſelf; at another diſtance, it cauſes it to recede, or move the con-

contrary way. The ſame ambiguous properties of this power obtain in Electricity, and undoubtedly in all other kinds of attractions. Therefore, before we endeavour to find out a Power, Spirit, or Æther, that ſhall move Bodies, either by attraction or repulſion, it is previouſly neceſſary to diſcover an Agent that ſhall do both; for ſuch a principle is, at preſent, the *deſideratum* to our further advances in the reſearch of natural Cauſes."

R. Is it poſſible that any Poſition ſhould be much more extraordinary than this? Which, ſuppoſing it true, then farewel all hope of ſucceſs in our future reſearches after the moſt neceſſary *natural Cauſes*; for what can ſeem much more impoſſible than to point out an Agent, which ſhall both attract and repel *? Are not two ſuch properties in the ſame Principle, deſtructive of each other, and therefore as incapable of ſubſiſting together, as Heat and Cold, Light and Darkneſs, or any other two of the moſt diametrically oppoſite Qualities?

* Had I, like Mr. *Barrow*, been ſo far deceived, as to think any one Agent poſſeſs'd of both an attractive and impelling Power, I might perhaps have fondly thought I had diſcover'd it, and have produced my vibrating Experiment, Part I. *Sections* 177. 179. to prove it; but the preceding Experiments, *Sect.* 175. 176. plainly prove that Attraction has no ſhare in them. Miſtakes of the ſame kind will appear in what he calls magnetic Attraction, when I come to animadvert on that Topic.

98.

98. Could Mr. *Barrow* ſo far deceive himſelf as to think that he was promoting the cauſe of Science, by advancing ſuch an abſurd, ſuch an unſcientific Aſſertion? What more effectual bar could he put on the door of Knowledge than to impoſe on the votaries, the more than Herculean Labour of producing a Principle of Nature which counteracts all her operations? A Principle which Nature directly diſowns and diſavows, ever invariably acting by conſiſtent and uncontradictory means.—— Are there not ſufficient reaſons to believe that Electricity may be much better accounted for without attraction, than with it? And ſince ſuch a *Power*, as a phyſical Agent to perform both, is abſolutely impoſſible in the nature of things, muſt it not be more ſatisfactory to attempt a rational method, whereby attraction may be totally excluded all reſearches after natural Cauſes? To me, at leaſt, a total excluſion of ſuch a miſtaken Principle appears to be abſolutely neceſſary to render our natural a *rational* Philoſophy.

Attraction ſhall therefore be the Subject of my next Enquiry. But as the retention of that Term has been ſo ſtrenuouſly defended, I cannot help foreſeeing that my utmoſt Efforts to remove the almoſt invincible prejudice in its favour may poſſibly prove vain and fruitleſs: But as I find Mr. *Jones* has copiouſly diſcuſs'd that Subject, I ſhall take the liberty of laying his Sentiments of it before the Reader in his

own words, which, on that and every other Topic he handles, are ſo pertinent, elegant, and entertaining, that I flatter myſelf I ſhall rather merit the Thanks than the Blame of my Reader for the largeneſs of my Quotations from him.

CHAP. VII. PART III.

SECTION 99.

The Opinion of Sir Iſaac Newton, *and of ſome of the moſt eminent of his Followers, relating to* Attraction and Gravity, *conſider'd at large.*

"IN the former Part of this Treatiſe," ſays Mr *Jones*, " I have made it appear, that the only rational and intelligible Philoſophy is that which attributes all motion to the action of matter upon matter; or, which is the ſame thing, that maintains an agency of material and ſecondary cauſes under the direction of God, the moral Governor of the World, and the ſupreme Cauſe of all things."

99. " To ſuch a Philoſophy as this, I have attempted to clear the way by removing all the principal objections of our modern learned Men; and if the ſuppoſed evidence for a vacuum, depending upon the famous theory of reſiſtances,

which gained ſo much credit with Dr. *Cotes*, and many others, as to be unhappily miſtaken for a *Demonſtration*; if this, I ſay, has been obviated to the ſatisfaction of the learned Reader, what remains to be done will rather be a work of eaſe and amuſement, than of difficult and doubtful diſputation."

101. "For if the notion of a *vacuum* be unſupported, and falſe in itſelf, nothing that is advanced in the mathematical Philoſophy, relating to *phyſical Cauſes*, can poſſibly be right. Where that Philoſophy has miſtaken or miſrepreſented the nature of theſe cauſes, it will be found inconſiſtent either with itſelf or with nature, and moſt probably with both; ſo that to detect the falſehood of it, we ſhall have nothing to do, but to compare it with itſelf, and with thoſe notions of the natural world, with which our Senſes and Experience will furniſh us. In this diſquiſition, we ſhall have in review before us, a great variety of uſeful and curious Experiments, which cannot fail of giving ſome entertainment, to a mind that hath beſtowed any of its attention upon ſuch ſubjects."

102. "As my concern at preſent is barely with phyſical cauſes, no reader can be ſo abſurd as to ſuſpect, that I am aiming at the demolition of all that is now called by the name of natural Philoſophy, without doing me a manifeſt injuſtice, and betraying his own want of Knowledge. The doctrine of unmechanical cauſes, tho' the forwardneſs and indiſcretion of ſome

adventurers may have loaded it with a much greater weight than it is able to bear, does yet make but an inconſiderable part of the eſtabliſh'd Philoſophy; and if it ſhould hereafter give place to ſome more natural account of things, the remaining parts will always retain their preſent value. Such a work as that of Profeſſor S' *Graveſande* will deſerve the admiration of the ingenious, ſo long as the world laſts; and that Man muſt have but an indifferent reliſh for the Sciences, who is not greatly delighted with the diſcoveries and improvements he may there meet with, in Mechanics, Optics, and Aſtronomy. I ſpeak this in much ſincerity: And it is intended to obviate any prejudices that might be raiſed againſt my deſign, either wilfully or by miſtake. To give offence is no part of my deſign; and I am unwilling, that any well-deſigning Perſon ſhould think me to be poſſeſſed by a ſpirit of detraction, while I am conſcious to myſelf it is far from me, and that I write upon much higher motives. I am encouraged therefore to hope for the attention at leaſt, if not the favour, of all candid Men and Lovers of phyſical truth, while I enquire into the ſenſe and merit of thoſe cauſes, by which the Author of Nature is now ſuppoſed to direct the natural world."

103. "Firſt then let us enquire, what kind of force or agency Sir *Iſaac Newton* and his followers would have us underſtand by the Terms *Attraction and Repulſion.*"

104.

104. "That *Attraction* hath been called in for the explication of natural appearances, both great and ſmall, every Perſon muſt know, who has either heard or read any courſe of phyſical Lectures deliver'd in Engliſh within this laſt Century: It is looked upon as a Principle, not to be approached without a degree of reverence, becauſe the great Sir *Iſaac Newton* thought proper to make uſe of it: but if the word ſhould have no fixed meaning, and ſhould itſelf want an explication, it will explain nothing at all; it will be a word without an *idea*; and if we apply it to any particular caſe, we ſhall explain, as the phraſe is, *ignotum per ignotius* a thing "*unknown* by another that is leſs "known." The word, if ſtrictly taken, ſignifies a *drawing* or *pulling* of one Body towards another: But as every Science hath a liberty of adopting its own Terms, provided it adds ſuch a definition as will keep them clear of ambiguity, I ſhall ſpend no conjectures upon it, but try if I can ſettle the three following queſtions, upon the beſt Authority that is to be had —— *Firſt, Where* Attraction is ſeated? for example, whether it be in the Earth, or in the Stone that falls down to it, or in both, or in neither, but in ſome ſubſtance exterior to both? *Secondly,* Whether it is to be underſtood as a *Cauſe* or as an *Effect*? And *Thirdly,* Whether it be a *material* Force, or an *immaterial* one? Under which heads, all that need be ſaid upon the ſubject may eaſily be reduced."

105.

105. "The principal ſpecies of Attraction, being that of *Gravity*, is deſcribed by Sir *Iſaac Newton* in his 5th Definition as a *centripetal Force*, whereby Bodies are *drawn*, *impelled*, or *tend in any manner* towards a Center: Which Definition is ſo far from giving any meaning to the word, that it rather ſeems to guard it, as it were, from having any meaning at all; there being a mixture of Terms here, oppoſite in Senſe to one another, ſuch as *Attraction* and *Impulſe*. To ſay a Body is *attracted* or *pulled*, is to place the power in that point, to which the Body is tending: To ſay it is *impelled* or *driven*, is to place the power *behind* it: But to ſay *both*, is to introduce two oppoſite forces, deſtructive of each other; which in effect, is to ſay *nothing*. This Definition therefore, as it now ſtands, will give us ſo little help, that we muſt divide it into two parts; that is, we muſt diſtinguiſh *Attraction* from *Impulſe*, as things diametrically oppoſite, and ſee to which of theſe two Sir *Iſaac* and his followers have inclined."

106. "If we look forward in the *Principia*, we ſhall accordingly find, that *Attraction* is the favourite term upon which all the learned Author's reaſonings turn; and that he ſuppoſes it to be a power ſeated *in the moved Bodies themſelves*, and in every *ſingle particle* of which they are compoſed. What elſe can we underſtand by * *corpora trahentia*, "drawing Bodies;"

* Lib. I. *Section*, 2.

and *corpora ſe invicem trahentia,* "Bodies that mutually draw each other," and * *ſphæræ ex materiâ attractivâ conſtantes,* "Spheres compoſed of *attractive matter ?* How again are we to eſtimate, as he directs, the Attractions of Bodies "by aſſigning to each of their particles their own *proper powers,*" † unleſs the *power,* by whatever *name* he pleaſes to call it, be as truly ſeated in the particles themſelves, as the force of reſiſtance, or *vis inertiæ* is ſuppoſed to be? And if the learned Author of this doctrine had not really ſuppoſed the ſolid matter of the parts themſelves to be endued with an active power, or principle of motion, he would not ſurely have taken ſo much pains to prove, that this power cannot be owing to any *Æther,* or other matter, external to the moved Body. For he ſets it down as the reſult of his Reaſonings and Experiments, that no ſpecies of matter can be *void of Gravity* ‡, whence the concluſion is obvious enough, that no matter can act as the cauſe of gravity, unleſs the *effect* of gravity in ſome bodies, can be the *cauſe* of it in others: which is abſurd."

107. "It remains then, the Gravity of all Bodies is owing to a *quality* ‖ reſiding in the Bodies themſelves; to which quality he gives

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* Lib. I. Prop. 72. † Aſſignando ſingulis eorum particulis vires proprias. Lib. I. p. 69. Schol.
‡ Lib. III. p. 6. Cor. 2. ‖ Hæc eſt qualitas omnium &c. ibid.

the

the name of *Attraction*. How much truth there is in the grounds of this conclusion, we shall see hereafter when Gravity as an universal property of matter is compared with Experiment."

108. "There are in the celebrated Works of Sir *Isaac*, so many passages seemingly inconsistent with the doctrine above mentioned, and especially that portentous paragraph with which he has concluded his *Principia*, that I would proceed with all due caution, and not venture to fix such an opinion upon him, without taking some farther counsel, and enquiring *how*, and *in what sense*, this doctrine has been received in the judgement of others, who subscribed to his opinions, and understood them throughly."

109. "Dr. *J. Keil*, who bestowed much pains in drawing out this principle of Attraction into a theory, has the following assertion —— *Materiæ inesse vim attractricem, confirmat experientia*, "Experience teaches us, that there is *in matter* an attractive power. This he calls —— *materiæ vis superaddita*, a force *superadded* to matter;" and again, *inest materiæ potentia, quâ singulæ, ex quibus constat, particulæ se invicem attrahunt* —— "There is a *power in matter* by which all its particles mutually attract one another *." So that in the constitution of all Bodies, there is a composition of *matter* and *power*; and if their parts are found, either to

* Philos. Trans. No. 315.

adhere,

adhere, or tend towards each other, we must ascribe it to a virtue in the parts themselves. If any heavy Body falls to the Earth, it is occasion'd by a *vis* or *potentia* superadded to the matter of them both; than which nothing can be more express to the point; and it shews us, to a demonstration, how *Attraction* was understood by Dr. *Keil.*"

110. "Dr. *Friend*, who endeavour'd to solve the operations of *Chemistry* by this principle, and was engaged in a controversy about it with some foreign Writers, was of the same mind with Dr. *Keil.* In the defence of his Lectures, he calls it—*principium attrahens, quod omni materiæ inest*—"A drawing principle that resides in all matter." And again he asserts—*Inesse immutabilem quibuscunque corporibus vim quâ itidem in sese mutuò ferantur*—"That Bodies are carried mutually toward each other by an immutable power within themselves *."

111. "Dr. *Clarke* in his Notes on *Rohault* informs us, that all those Bodies will ascend in water, which are less attracted by the Gravity of the Earth than Water itself †. Whence it appears, that according to his notion of the affair, Attraction is a quality residing in the matter of the Earth itself; it being the *gravitas telluris*, to which the effect is imputed."

112. "To these Authorities, I may add that

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* Philos. Trans. No. 331. † Quæ telluris gravitate minus sunt attracta, P. I. ch. 22. §. 15.

of the ingenious Mr. *Rowning*; who, ſpeaking of the Attraction of Gravitation, obſerves in very plain terms, that "The action of the Earth upon Bodies is exactly in proportion to the matter they contain *."

113. "But above all, the opinion of Dr. *Cotes* is to be regarded; and it is more to my purpoſe than any of the former. "We are to believe, ſays he, that the action of the Earth is compoſed of the joint actions of all its parts; and therefore, that all terreſtrial Bodies ought to attract one another with abſolute forces, which are in a direct ratio of the drawing matter †."

114. "All theſe Authors then (and I might have added many others) who have followed the Newtonian hypotheſis, declare with one voice, that when a terreſtrial Body is ſo acted upon as to deſcend to the Earth, the drawing matter of the Earth itſelf is the agent; and it acts by a power ſuperadded to it, which power they call Attraction. All the other kinds of Attraction, ſuch as that of Magnetiſm, Coheſion, Electricity, and Repulſion the antagoniſt of them all, are to be underſtood in the ſame way: But I forbear to weary the Reader's patience

* Vol. I. p. 15. † Actio itaque telluris ex conjunctis partium actionibus conflari cenſenda erit; atque adeo corpora omnia terreſtria ſe mutuo trahere oportet viribus abſolutis, quæ ſint in ratione materiæ trahentis. See his Pref. to Sir *Iſaac*'s Principia. p. 3.

ſience with any particular proofs of it. This, I remember very well, is the ſenſe in which I myſelf, in common with other young Men, underſtood the doctrine of Attraction, when I was initiated into theſe myſteries of natural Philoſophy: It is the ſenſe in which I thought Sir *Iſaac* did originally deſire to be taken; and in which, I am confident he is taken to this day, by very many Readers. I am now perfectly eaſy about it, being in the company of thoſe Writers, whoſe learning and candour, with regard to their Author, have never yet been diſputed."

CHAP. VIII. PART III.

SECTION. 115.

An Examination of the Queſtion, whether Attraction *be a* Cauſe *or an* Effect?

"IT will now appear very ſtrange, our Author proceeds to obſerve, to aſk whether Attraction be a *Cauſe*, or an *Effect*; *Action*, *Force*, *Power*, &c. having all been aſcribed to it: But this enquiry will anſwer a very good purpoſe, and ſerve abundantly to convince the unprejudiced, that they, who brought this Principle into faſhion, did never yet know what to make of it."

116. "Mr. *Leibnitz*, and many other learned Mathematicians, were for exploding *Attrac-*

tion at its first appearance; they even ridiculed it as unphilosophical, unintelligible, an *occult* Quality, and a Miracle; and absolutely denied its very existence. Observe therefore what a reply Dr. *Clarke* made upon the occasion——"It is very unreasonable to call Attraction a "miracle and an unphilosophical term, after it "has been so often distinctly declared, that by "that term, we do not mean to express *the* "*cause of Bodies tending towards each other*; but "barely the *effect* of this cause, or the *Phæno-* "*menon itself* discover'd by experience, what- "ever be, or be not the cause of it. Gravitation "or Attraction *in this Sense* (he adds) is an ac- "tual Phænomenon of Nature." And again; "Philosophers therefore may search after and "discover that cause if they can, be it mecha- "nical or not mechanical: But if they cannot "discover the cause, is therefore the *effect itself*, "the *Phænomenon*, or the *matter of fact disco-* "*vered by experience* (which is all that is meant "by the words *Attraction* and *Gravitation*) "ever the less true?" Mr. *Leibnitz* objected to *Attraction*, as to a *cause*, occult and unphilosophical: Dr. *Clarke* answers him, by denying it to be any *cause* at all; for that it means nothing more than the bare *effect*, or *Phænomenon* of a *tendency* in one parcel of matter toward another. And if this were all, who could take any offence at it? For that there is such a tendency, experience will indeed convince us; and there are few Astronomers, who will not allow

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of it, even in the heavenly Bodies themſelves. But then the Authority, to which this Author has referred us, is no way to be reconciled with his account. The words of Sir *Iſaac* are theſe: " I uſe the word Attraction, only in general, " to ſignify the *force* by which Bodies *tend* to- " wards each other." Dr. *Clarke* aſſures us very poſitively, and deſires he may not be miſunderſtood, that when Bodies are ſaid to be *attracted* or *gravitate*, nothing farther is meant, but that they are found by experience to *tend*: Whereas Sir *Iſaac* affirms, in the very words to which he has referred us, that Attraction expreſſes that *force* in general *by which* they tend; and theſe two are as diſtinct as a cauſe and an effect can be; juſt as different, as is the tendency of a Bullet toward the mark, from the *force* of the Gunpowder, *by which* it is ſent from the Piece. And the following words are ſufficient to prove, that notwithſtanding what Dr. *Clarke* might think it convenient to ſay to Mr. *Leibnitz*, Sir *Iſaac* did not publiſh his Attraction of Gravity to the world under the notion of an effect——" It is enough, ſays he, " that *Gravity* really exiſts, and *acts* according " to the Laws we have laid down;" which an *effect*, I think, can never be ſaid to do, without a childiſh abuſe of Language."

117. " Let us next examine the opinion of Dr. *Cotes*, who thus appeals to his Adverſaries, in behalf of the *Newtonian* Gravity—— " Would you call Gravity an *occult cauſe*, be-

" cauſe

" cause the cause of Gravity is occult, or not " yet found out?" No, certainly I would not: For if its *cause* remains yet to be discover'd, I would have observ'd the caution given by Dr. *Clarke*, and have called it an *effect*. For if Gravity be a physical cause, we have already gain'd our purpose, and the Science of Physics does not require us to look for another. If it be a cause of so mysterious a nature, that no physical account can be given of it, it must be classed among those occult Qualities, which the scholastic Philosophers affirmed to have a real existence, tho' they were unable to give any farther account of them. We have the Authority of Dr. *Cotes* however, that Gravity is a *cause*, which was just now affirmed to mean nothing but an *effect*; and the Adversaries of this Philosophy were charg'd with the *unreasonableness* of a contrary supposition. From what this Author hath written, it appears he never suspected Gravity to be any thing but a cause, even the most simple of Causes, beyond which human Knowledge cannot possibly penetrate——*ubi ad causam simplicissimam perveneris* (such as he supposes Gravity to be) *jam non licebit ulterius progredi*. He thinks there is a concatenation of physical causes in the world, some compounded, others simple and primary; but *Gravity* he places among the *causas simplicissimas*, and *causas per Phænomena comprobatas*; which latter expression sets him in a direct opposition to Dr. *Clarke*; with whom Attraction and

Gravity

Gravity mean nothing but the bare effect or Phænomenon itself: Here, it is the *Cause*, proved *by the Phænomenon*. And it should be remember'd for the justification of Dr. *Cotes*, that he wrote in the year 1713, Dr. *Clarke* in 1717. Dr. *Desaguliers* will inform us, that "*Attraction* "and *Repulsion* seem to be settled by the great "Creator as first Principles in Nature, that is, "as the first of *second causes*; so that we are "not solicitous about *their* causes, but think "it enough to deduce other things from them." This confirms the reflexion I made a while ago; that Attraction is a cause, of which no account can be given; and that it serves to keep us under the same ignorance with the occult qualities of the Schools. It was for this reason only, that the learned Men of the last Age remonstrated against it with so much earnestness; and Sir *Isaac*, in order to remove the offence it had given, took the matter a second time into consideration. When he view'd it in a physical light, he concluded from some particular Experiments, "that there are *Agents in Nature* able to *make* "the particles of Bodies stick together by very "strong attractions; and that it is the business "of experimental Philosophy to find them "out;" that is, to find out those *Agents of Nature*, which act as the immediate *Causes* of this *Attraction*. By which remarkable concession, Sir *Isaac* himself, who elsewhere makes Attraction a *Force*, and Gravity an *active Principle*, has reduced them both to *Effects*; encouraging

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us at the ſame time to enquire experimentally after thoſe Agents of Nature, by which theſe effects are brought about; while *Deſaguliers* his Diſciple lays down Attraction itſelf as the *firſt of ſecond Cauſes*; and Dr. *Cotes* aſſures us, that if we get ſo far, *jam non licebit ulterius progredi.*"

118. "If we aſk the opinion of Dr. *Friend*, he will tell us, Gravity is an effect, and Attraction is the cauſe of it. This *Attraction* (which he had juſt before called the *force of Gravity)* "they may, if they pleaſe, call an occult Quality; and I believe it will always be occult:" Yet, in another part of the ſame diſcourſe, he ſays, "In explaining this Gravity, which is evident to ſenſe, *Newton* hath far exceeded all other Philoſophers; having demonſtrated it to ariſe from an *attractive Force*, which diſperſes itſelf far and wide thro' all matter." From which paſſages, we may learn theſe three things: *Firſt*, that Gravity and Attraction are the ſame thing, becauſe the Author, ſpeaking of the *vis gravitatis*, calls it—— *hæc attractio*. *Secondly*, that Attraction is an *occult Quality*, and always like to remain ſo. *Thirdly*, that *Gravity* is *beſt explain'd by Attraction*; tho', by his firſt ſuppoſition, they are the ſame thing; and then Gravity is beſt *explained by itſelf:* By the ſecond, Attraction is allowed to be an occult quality, and he believes it will always remain ſo. Which doctrine comes out juſt as it ſhould do; for to explain any thing by an oc-

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cult quality, is to explain it by itſelf: And in this abſurdity, the *cauſes* propoſed by the mathematical Philoſophy will all be found to terminate."

119. "How oppoſite to thoſe of this laſt-named Author, were the ſentiments of the celebrated M. *Maupertius*; who thus apologizes to the French Academy in behalf of the *Newtonian* Attraction? ——"Many People, ſays he, "have been diſguſted by the word *Attraction*, "expecting to ſee the doctrine of occult quali-"ties reviv'd again in natural Philoſophy; but "in juſtice to Sir *Iſaac Newton*, it ſhould be "remember'd, he has never conſider'd Attrac-"tion as an explanation of the Gravity of Bo-"dies toward each other; he has frequently "warned us, that he employs this term, not to "ſignify a *cauſe*, but only an effect." Therefore in the judgement of this learned Man, whoſoever recommends Attraction to us as a phyſical *cauſe*, or an *explanation* of effects, revives the doctrine of occult qualities."

120. "*Laſtly*, let us hear the opinion of Mr. *Rowning*, a Writer who has done much ſervice to the public, by giving us a regular Treatiſe upon natural Philoſophy in all its branches. But alas! we ſhall find him to have fallen into the ſame inconſiſtency with the other Writers who went before him; which I would impute wholly to the perplexed condition of the ſubject, and not to any intention of deceiving in the Author. "It is to be obſerv'd (ſays he)

"that when we uſe the terms *Attraction* or "*Gravitation*, we do not thereby determine "the phyſical cauſe of it, as if it proceeded "from ſome ſuppoſed occult quality in Bodies; "but only uſe thoſe terms to ſignify an effect, "the cauſe of which lies out of the reach of our "Philoſophy. We may ſay that the Earth at-"tracts heavy Bodies, tho' at the ſame time "we are wholly ignorant whether this is ef-"fected by ſome power actually exiſting in "the Earth or in the Bodies, or external to "both."

121. "Now altho' *Attraction* be an unhappy word by which to expreſs an effect, yet if Mr. *Rowning* were conſiſtent with himſelf in this matter, and carried the thing no farther, it would be well enough: But the contrary will ſoon appear, from a few ſhort remarks upon this paſſage. *When we uſe the Terms Attraction or Gravitation, we do not thereby determine the phyſical cauſe of it.* Of what? Of Attraction? *That* is not the thing required. We only deſire to know, whether Attraction really exiſts in nature, as a *force* or active principle; and whether we are to underſtand it as a *cauſe* of natural effects? or whether it be barely the *Phænomenon* of a tendency or motion, the cauſe of which is yet to be ſought after? It can never be expected, that the word *Attraction* ſhould be expreſſive of its *own cauſe*; eſpecially if it be one of Dr *Cotes'* moſt *ſimple of cauſes, and ſuch as hath no dependence upon any other*. The

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complaint is this; that Attraction is proposed to us as an effect; but if once admitted, it is thenceforward forced upon us as a *cause*; as a solution of every difficulty; while Attraction itself is the greatest difficulty of all. That it is applied as a cause by Mr. *Rowning*, I shall shew hereafter: That it is not to be understood as an effect, may be proved from his own definition of it. "Matter, says he, has also certain "*powers*, or *active principles*, known by the "names of *Attraction* and *Repulsion*, impressed "upon it by the Author of its being, for the "better *performance of the offices* for which it "was designed." If Attraction, as the Author says elsewhere, be a term used only to signify an *effect*, how comes it to be here described, as a *power* or *active principle*; which are appellations utterly repugnant to the notion of a natural *effect*? Can an effect *perform offices*, and be *active* toward the production of an effect? That surely must be the work of an agent or physical cause; and Attraction must undoubtedly be taken for such, if it can be proved to perform any physical offices. But, says Mr. *Rowning*, "we are wholly ignorant whether this is ef- "fected by some power, actually existing in "the Earth, or in the Bodies, or external to "both." And here he seems to have forgotten his own definition of Attraction; it being a *power impressed upon* matter; others say, it is *in* the matter, and that the point has been *demonstrated*. But if after all this, we are wholly

obſcurity, either ſtudied or unavoidable; and in all the Paſſages I have been able to collect and compare, there is ſomething that appears like a *ſlight of Hand*, whereby the *effect* is ſhifted into the place of the *Cauſe*. As I am unable to draw any Doctrine from the whole with preciſion, it will be beſt to introduce the Authors giving their verdicts in their own Words, and leave the Reader to his own Judgement."

Sir *Iſaac Newton*. "Gravity exiſts and *acts*."

Dr. *Friend*. "In *explaining* Gravity, *Newton* has demonſtrated it to ariſe from an *attractive force*."

M. *Maupertius*. "It ſhould be remembered in juſtice to Sir *Iſaac Newton*, he has never conſidered *Attraction* as an *explanation of Gravity*. He conſiders it not as a *cauſe*, but as an *effect*."

Dr. *Cotes*. "Gravity is the moſt ſimple of *Cauſes*."

Dr. *Clarke*. "It has often been diſtinctly declared, that by the term *attraction*, we do not mean to expreſs the *cauſe* of Bodies tending toward each other, but barely the *effect*, the *effect itſelf*, the *Phænomenon*, or *matter of fact*."

125. Dr. *Deſaguliers*. "*Attraction* ſeems to be ſettled by the great Creator as the *firſt of ſecond cauſes*.

126. Mr. *Rowning*. "When we uſe the

"term

"term *Attraction*, we do not determine the
" physical cause of it, but use it to signify an
" *effect*: Nevertheless, to attraction effects are
" *manifestly owing*."

127. Sir *Isaac Newton*. "There are *Agents*
" *in Nature* able to make the particles of Bo-
" dies stick together by very strong *Attractions*,
" and it is the business of experimental Philo-
" sophy to *find them out*."

Dr. *Desaguliers*. " We are not solicitous
" about the *cause of Attraction*."

Dr. *Friend*. " I believe *Attraction* will al-
" ways be *occult*."

128. " This is the result of my enquiry: And if any Person should be so inclined, he is welcome to lay all the blame upon my want of understanding. But if these learned Men, who are all vindicating the self-same Principles of Philosophy, had no clear ideas of what they affirmed, and could not understand *one another*; it is no wonder, if the World should be at some loss to understand *them*."

CHAP.

CHAP. IX. PART III.

SECTION 129.

Attraction, a material *force in the Judgement of some Authors*; *an* immaterial *force in the Judgement of others*; *and sometimes both* one *and the* other *in the Judgement of the* same *Author*.

THE Motive, which excited the Rev. Mr. *Jones* to present the World with his curious Essay on the first Principles of natural Philosophy, was his manifest dissatisfaction with that system of Physics which had been before received.

130. That discerning and accomplished Author, conscious of the honest but obnoxious Task he had undertaken, judiciously remarks how formidable and destructive *Authority* has often proved to the progress of true Learning; which brought to my mind a pertinent observation of Bishop *Hoadly* on Authority with regard to Religion. His words are.

131. "Authority is the greatest and most "irreconcileable Enemy to truth and argument "that this world ever furnished out; all the "sophistry, all the colour of plausibility, all "the artifice and cunning of the most subtle

Disputer

" Disputer in the world may be laid open, and " turned to the advantage of that very Truth " which they designed to hide or to depress: " But against Authority, there is no defence." ——This will be found to hold equally true with regard to Philosophy; which if so, the first necessary step must be to pass a strict scrutiny on the several pretensions to true Philosophy in general, without the least reserve or regard either to names or their several opinions. But to return to Mr. *Jones'* Observations.

132. " We have, says he, yet a third Question to settle, *viz.* whether *Attraction* be a *material* force, or an *immaterial* one? And here we shall have the same scene as before; this point being left equally undetermined with the former. Indeed nothing can be more evident, than that Sir *Isaac Newton* great as he was, hath offer'd to the world his Thoughts on a Question of much importance, and taken *both sides* of it. It is disagreeable for me to say this; but it must be said, because it is certainly true; and I cannot go forward without saying it. This, as we shall find, has divided his followers; and their disputes with each other in regard to first Principles and Fundamentals, have as great an appearance of fallibility and uncertainty, as other disputes used to have, before the Science of natural Philosophy was enrich'd with demonstration: Of which I shall exhibit a notable instance, from the Writings of the celebrated Mr. *Maclaurin*, and his Antagonist, the Author of

an *Enquiry into the Nature of the human Soul.*"

133. "But firſt let us attend to Sir *Iſaac* himſelf. There is a Paſſage in his *Optics*, wherein he allows, that what he imputes to *Attraction* may be performed by *Impulſe* *. Dr. *Clarke*, in his Notes on *Rohault*, cites this Paſſage; and leſt we ſhould take the impulſe here ſpoken of, to be that of ſome intervening *Matter*; he inſerts by way of comment—— *non utique corporeo* ——† declaring, that this *impulſe* is *not corporeal*; or, in other words, that it is not the impulſe of any material Agent. We have the ſame ſentiment from him upon another occaſion—— "It is now allow'd on all "hands, that Gravity does not depend on the "action of the Air, or *Æther*; but is a pri-"migenial, innate, and unchangeable affection "of all matter ‡." This is in anſwer to the great Dr. *Wallis*, who was of another mind. He ſuſpected that Gravity, tho' uſually taken for a primary quality, might be owing to the *percuſſion* of ſome impelling matter, and propoſed a ſhrewd caſe to countenance his opinion: But I forbear to ſay any thing farther of it in this place."

134. "Mr. *Rowning*, who has laid down the receiv'd Philoſophy with as much diligence and fidelity as any Man, hath affirm'd nothing

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* P. 351. † P. 51. ‡ Verum cum jam in confeſſo ſit, gravitatem non ab aere *ætherev*e pendere, ſed eſſe primigeniam, connatam, immutabilemque materiæ affectionem *&c.* p. 61.

so

ſo expreſſly, as that " theſe *Diſpoſitions* in Bo-
" dies (ſuch he calls gravitation, attraction,
" *&c.)* are not the reſult of any mechanical
" Cauſe whatever; that is, ſuch as may ariſe
" from the action of any material ſubſtance *."
And he has treated his mathematical Readers with a Demonſtration, proving the impoſſibility of it. Profeſſor S' *Graveſande*, from whoſe great abilities we might have expected ſomething more ſatisfactory, unhappily fell into the ſame way of reaſoning; and gave a geometrical demonſtration (as he thought) that the ſpherical Figure of a drop of water cannot be occaſion'd by the *equal preſſure* of any fluid Medium."

135. " More Authorities to the ſame purpoſe might eaſily be produced; but this doctrine hath been ſo largely maintained by ſo many Writers, that I muſt have the aſſent of the learned, if I ſet it down as a doctrine of Sir *Iſaac Newton.*"

136. " But then, on the contrary, it is to be remember'd, that this introducing of immaterial impulſes into the world of matter, firſt raiſed a clamour againſt his Philoſophy, as tending to revive all thoſe occult qualities, which had been ſo happily baniſhed, but a while before, from all Books of natural Philoſophy. To obviate

* Pref. p. 6. Dr. *Cotes* hath affirm'd the ſame, in his preface to the ſecond Edition of the *Principia* —— *Gravitas* —— *ex aliis corporum affectionibus atque adeo ex cauſis* mechanicis *originem* non *habet*. p. 9.

this, and to *shew*, as the Author expresses himself, "that he did not take Gravity for an essential property of Bodies," *he added a Question concerning its Cause**. This *Cause* he supposes to be a *subtile ætherial Medium —— readily pervading all Bodies —— expanding through all the Heavens —— causing the* Gravity *of those great Bodies* (the Sun, Planets, Comets, *&c.*) *towards one another, and of their parts toward their Bodies* —— and such as *may suffice to* impel *Bodies from the denser parts of the Medium toward the rarer with all that Power which we call Gravity* †. This I say, is proposed as a *material Cause*. For, is it not a *Medium*, capable of *rarity* and *density*, subject to a kind of *vibrations* or pulses? And an *immaterial Medium* would be an *ens rationis*, a philosophical spectre, a contradiction in terms."

137. "Here then, we have two different Systems of Philosophy. According to the former of them, all the operations of Nature are conducted by means of *unmechanical* and *immaterial impulses* in a *Vacuum*; but according to the latter, they have, as their immediate *Cause*, an *Æther* expanded thro' all the Heavens: And he that shall take up either with the one or the other, or with the one against the other, will have Sir *Isaac Newton* on his side. But whoever shall assume them *both* as true, will bring himself into great distress and difficulty."

* Opt. Advert. II. † See Opt. Q. 18. 19. 20. 21.

138. "This was the fate of the ingenious Mr. *Maclaurin*, a learned and elegant Writer, who undertook a formal defence of the *Newtonian* hyphothesis against all the Objections that had been made to it; and was well qualify'd, if any Man could be so, for the undertaking. He understood his Subject perfectly; and was sensible he could never do justice to the *Principia*, without banishing all material Causes from the Heavens. This he attempts to do, tho' it is frequently with some reserve, in several parts of his Treatise; particularly in the following Words —— "As for a more subtile Medium than the Air, no Experiments nor Observations shew, that there is any here, or in the celestial Spaces, from which any sensible *resistance* can arise*." Mr. *Maclaurin* was very well inclin'd to admit a material Agency in subordination to the first Cause †; but this false doctrine of *resistance* tied up his Hands; otherwise his Work might have been all of a piece. As it stands now, the most valuable passages in it, are so many contradictions to all the rest. After what he has said above, who would expect to hear him reflect upon "others, who while they overlook the intermediate *Links* in the *Chain of causes*, and hastily resolve every Principle into the *immediate influence* of the first Cause, impair the Beauty of

* P. 294. † This is very manifest from the the 14th *Section* of his last Chapter.

Nature, put an end to our enquiries into the *most sublime parts of Philosophy*, and hurt those very interests they would promote*?" They do so most undoubtedly: But hath not the mathematical Philosophy this tendency? Doth it not oblige us to deny, against reason and our better Knowledge, that *any Experiments or Observations shew that there is a Medium more subtile than Air*? Hath not Mr. *Maclaurin* himself deny'd it in these very Words? And elsewhere in the most categorical terms, he hath asserted an absolute *vacuum* — "Sir *Isaac Newton*'s Philosophy (says he) has shewn, that not only there may be, but that there *actually is a vacuum*— that Matter appears to occupy but a *very small portion* of space †." If this should be true, what becomes of *his chain of Causes*? For if there be no Medium concerned as a secondary cause in the motion of the Planets, &c. it follows unavoidably, that there must either be inherent and self-moving *Powers in Matter*; or that the influence of the first Cause, must be *immediate*; for there is nothing else remaining, and then Mr. *Maclaurin*'s Chain will consist but of one link. This is the Opinion, which he thinks, must *put an end to our enquiries into the most sublime parts of Philosophy*. And lest it should be suspected, that Sir *Isaac*'s method of Philosophizing has introduc'd *immaterial Powers* and occult qualities, we are assur'd by this Author, that "he does never affirm or insinuate that a Body can *act upon another at a distance*,

* P. 95. † P. 77. but

but by the intervention of other Bodies*."
But his zeal hath carried him a little beyond the Truth: The thing he here denies, being much more than *insinuated* in these Words— "Have not the small Particles of Bodies, certain *powers*, virtues, or forces, by which they *act at a distance*, not only upon the rays of Light—-but also upon one another, for producing a great part of the Phænomena of Nature? For it is well known that Bodies *act upon one another* by the *Attractions* of Gravity" *&c* †."

139. "Attraction, as a power acting *at a distance*, is here left in full possession; not a Syllable being inserted, as I can find, concerning the *intervention of other Bodies*. If this intervention were admitted, how would it agree with what Dr. *Clarke* has so frequently inculcated throughout his Notes on *Rohault*'s physics? He sticks not to assert an *impulsus non utique corporeus*, and an *actio causæ cujusdam immaterialis*——*per injectum aliquod intervallum* &c. See p. 50. Besides, the sense of the whole passage, would be overthrown by Mr. *Maclaurin*'s supposition; for if other Bodies intervene, then Attraction will not be a power acting *at a distance*, but by a *communication* of Bodies that are in contact. The Author (Sir *Isaac Newton*) does indeed inform us a while after, that he uses this Word to *signify only in general any force* ‡ &c. but this does not alter the Case:

* P. 109. † Opt. Q. 31. ‡ Ibid.

For

For let it be a force *in general*, yet it hath this *particularity* in it, that it *acts at a distance*, which is the Nature of an *occult quality*, and is the very Thing that has all along been objected to. And though Mr. *Maclaurin* hath taken great pains to get handsomely rid of this unintelligible power, yet is the existence of such a power absolutely necessary upon his own Principles. Sir *Isaac*, he says, hath shewn, that there *actually is a Vacuum*, and that the *parts of Matter are actually divided and separated from each other*: After which it would be strange indeed, if they were to *act* otherwise than in this state of *division and separation*, that is, *at a distance*. When he supposes other Matter to *intervene*, till the action will consist with Mechanism, he apologizes for a *Vacuum*, at the expence of the Principle itself; which by this means is turned into a *Plenum*, whether the Author was aware of it or not."

140. "How unseasonably therefore was it observ'd by Mr. *Maclaurin*, that "possibly some unskilful Men may have fancied, that Bodies might attract each other by some Charm or *unknown Virtue*, without being impell'd or *acted upon* by other *Bodies* *?" For if this was not a fancy of Sir *Isaac Newton* himself, in common with some of the most skilful of his followers, the plainest English can have no meaning. I know very well, his Writings contain many passages, which seem to have a con-

* *Ubi sup.*

trary

trary meaning: And his Difciples find fuch an advantage in this, that they have an Anfwer ready upon all Occafions. For Example, if you fuppofe the World to be ruled by a fubordination of material Inftruments, in oppofition to Sir *Ifaac's* Vacuum; then you are told, there is *no Medium more fubtile than Air*; that the Heavens are *void of all fenfible Matter*; and it is demonftrated againft you *geometrically*, that attraction *cannot arife from the action of any material fubftance whatfoever*. If you fhould lay hold of this, and object to attraction as a Principle *occult* and *unphilofophical*, then it is only the *fancy of fome unfkilful Men*; and Sir *Ifaac Newton* has *plainly fignified, that he thought that thofe powers arofe from the impulfes of a fubtile ætherial Medium that is diffus'd over the Univerfe**. Thus you are confuted either way; and your reafoning is reprefented as *crafty difingenuous*, and *unworthy of a Philofopher* †."

141. "By this artifice, Mr. *Maclaurin* would have quieted all our Scruples; but feems to have mifcarried in the attempt, having been oblig'd to contradict his Author *in terminis*; and I may add, *himfelf* alfo; as it hath been fully proved againft him by Mr. *Baxter*, the Author of an *Appendix to an enquiry into the Nature of the human Soul.*"

142. "There are two different modes of Philofophy before us, both of which have Sir *Ifaac*

* *Maclaurin's* Phil. Difc. p. 111. † See p. 110.

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Newton at the Head of them, Mr. *Maclaurin* by espousing them *both*, fell upon various contradictions. Mr. E—— is more cautious; and hath written with some warmth on one side, against Mr. *Maclaurin*, who is on both sides. Where the latter hath really laid himself open, he makes good use of the opportunity; without considering where, and upon *whom*, his Censures will at last be fix'd*. He is clearly of Opinion, that the material Causes, occasionally introduc'd by his adversary, are utterly inconsistent with what is establish'd in the *Principia*; and is therefore a declar'd Enemy to all *subtile Matter*, even to that *Æther* of Sir *Isaac*, for which Mr. *Maclaurin* hath pleaded as handsomely as the nature of the thing would admit. Men of leisure (he says) have amused the world with wrangling and contest—— by a succession of *subtile matters* from the earliest times—— But it requires only plain sense, and a love of truth, to see thro' the imposition†. It is injurious, he thinks, to that great Man's reputation, to bring in his Authority, for a thing which he asks only by way of a *query*, as if he had been positive; and that it is an ill office done to his memory. But this is a reflexion, which, in my humble opinion, his Adversary did not deserve: And it should be consider'd in his vindication, that tho' a *query* may shew Sir *Isaac* not to have been *positive*

* See *Append.* the Note at p. 113. † P. 66.

about

about the *manner* in which his *Medium* acts; most certainly it doth also shew, he was not positive that no such thing existed; especially as he hath mentioned an Experiment to prove the existence of a subtile matter which has never yet been answered *. By what Authority then is this Writer so positive? And what will be the consequence of it, when it *requires only plain sense, and a love of truth*, to see that he is disputing for one half of Sir *Isaac Newton*, against the other half? The Authority of that great Man is indeed like to be killed, not by the malice of his enemies, but by the kindness of his friends; if some of them think an *ill office is done to his memory*, while others think they are offering the only expedient in vindication of it."

143. " This learned Author presents us with the *attraction of cohesion*, as *an universal Phænomenon, that ought to silence the advocates for material Causes in all cases* †; and *promises to be silent, if all the Philosophers upon earth can account for it, otherwise than by the power of the Deity immediately interested*, &c. He judges it *very unartful to suppose the* Deity employing one part of matter to move or direct *another part of it* ‡, tho we see it done every day of our lives.——And that no *subtile matter* can act as the *cause* of *Gravity*, unless it *knows* what it it is doing ||. These and some other *Difficulties*

* See *query* 18. † P. 62. ‡ P. 49. || P. 117.

of the same size, he thinks to be so great, that *there is no subterfuge* *: tho' it might easily be shewn, there is not one case of any concern rightly stated throughout his whole Book; and that every Article he has built upon is confuted by Experience. These considerations, I presume, tempted Mr. *Maclaurin* to pass sentence upon his whole System in these words——— He has done this valuable service, that while he vainly imagined he improved or compleated it, he really open'd up the fallacy, and reduced it to an absurdity."

144. "I proposed it as a question, whether Attraction be a *material* force or an *immaterial* one? And we have now consulted those Writers, who ought to have settled the point for us. If Sir *Isaac* hath really *established* any thing on either side, in regard to physical Causes; it is astonishing his followers have not fixed upon it, and recommended it to the Public with one consent; especially if there be any thing of importance depending upon it. But if, on the other hand, the sentiments of their Master have given occasion to these disputes, and his Writings have furnished them with Arguments on both sides; then he himself is chargeable with some inconsistency; and a general agreement among them, in such a case, would be as much to be wonder'd at. That this latter is the true cause of all their disagreement, will be evident to any Reader, who is not so far influenced by the current Authority, as to be deterred from

* ibid.

making

making ufe of his own Reafon. For if you learn from one page that it is part of the bufinefs of a Philofopher *to unfold the mechanifm of the World**, and that an *ætherial Medium* may *fuffice* to *impel* Bodies †; in another it is hinted to you, that the fmall particles of Bodies may have certain *Powers* by which they *act at a diftance*——*by attractions* ‡. If you are informed in one place, that when the rays of Light are reflected from the *fecond furface* of a Glafs laid upon an *exhaufted Receiver*, this *total reflexion* ought to proceed from the *vigour* and *denfity* of the *Medium beyond the Glafs* ||: Only obferve where the fame Experiment is mentioned in another place, and you will find, the Light is now *drawn* back, and that, by the *power of the Glafs*, there being *nothing elfe to turn it back*** ; tho' a while ago there was a *Medium* to perform this, endued with *vigour* and *denfity*."

145. "It is fuggefted, that this *Medium* may act upon light fo as to *reflect* and *refract* it ††, and that the *Light* in its turn may re-act upon the Medium fo as to *ftir up vibrations* in it: But foon after, it becomes "inconceivable, "how two Æthers can be diffufed through all "fpace, one of which acts upon the other, and "by confequence is re-acted upon, without "retarding, fhattering, difperfing, and con"founding one another's motions ‡‡."

* Opt. 3d *Edition*, p. 344. † Q. 21. ‡ Q. 31. || Q. 19 ** Q. 29. †† Q. 18. 20. ‡‡ P. 339.

146. "I could multiply instances of this sort, wherein the celebrated Author has pulled down with one hand, what he had built up with the other: But if Men will dare to use their own Reason, as I said before, they may easily observe these things for themselves."

147. "If we go from Sir *Isaac* to his followers, there the confusion will be still more manifest. Drs. *Cotes*, *Clarke*, *Derham*, *Keil*, *Friend*, *Desaguliers*, Mr. *Rowning* &c. instruct us, that *matter* has *powers*, *forces*, *principles*, *affections*, *properties*, *impressed* upon it, *superadded* to it, or *inherent* in it; and that God, when He created the World, *inspirited the materials of it with an active quality*. This was the original doctrine of the mathematic philosophy, and the sense in which it was first embraced by the learned. As it gave Birth to many ill-favoured reflexions, it is now almost out of fashion; and Mr. *Maclaurin* rises up to vindicate Sir *Isaac*, by a substitution of his subtile *Æther*, as the mechanical and immediate Cause of all that had been falsly imputed to *attraction* by *unskilful* Men. This stirs up the indignation of another; who out of the highest regard to the *memory* of Sir *Isaac*, pulls this vindication of him all to pieces, represents it as worse than none at all, rejects all *subtile matter* in the lump, and recommends the *immediate Influence of the Deity*, as the grand discovery, and the only cure for all disputes. But for his pains, he is instructed in his turn, that his own labours have only *served to open up*

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the fallacy of his Scheme, and reduce the whole to an abſurdity. There have been heavy Complaints, that the Philoſophy of Sir *Iſaac* hath been *depreciated*, and *even ridiculed**. And is it not enough to diſcompoſe the muſcles of an hermit, to ſee Men thus notoriouſly contradicting one another, and all gravely pretending to *Authority* and *Demonſtration!* They tell us, there has been a great *Diſcovery* of late years in natural Philoſophy; it having been found at length, after the world had been in ignorance for many ages, that all matter is endued with *Attraction.* If you aſk them what they mean by it; it is—— an innate virtue or affection of matter; while others affirm, matter can have no ſuch affections. It is the moſt ſimple of *Cauſes*, and an *effect*, the cauſe of which is unknown; it is owing to the agency of a *ſubtile Medium*; and it is effected by the *immediate influence of the Deity:* And if you do not believe this principle, and make uſe of it to *explain* every thing, you are out of the faſhion, and what you have to ſay will be very coldly regarded."

148. "As we cannot poſſibly believe *all* theſe opinions, we are not bound to believe any one of them upon the bare *authority* of Sir *Iſaac Newton.* If we are to receive one of his opinions in this way, why not another? the authority which is broken through in one article, will at leaſt be queſtioned in every other. If it be ſaid, we have reaſon to prefer ſome of his

* Philoſ. Diſcov. p. 110.

his sentiments to others; then we are influenced, not by authority, but by reason or evidence; and hitherto I would willingly bring this matter. Reason and Evidence must determine us at last, tho' the fame of Sir *Isaac Newton* were as universal now, as that of *Aristotle* was formerly. His warmest Friends take this liberty with him. Mr. *Maclaurin* rejects his immaterial powers, *acting at a distance*; Mr. *Baxter* makes as free with his Medium, yet is greatly displeased with his Adversary for lessening Sir *Isaac*'s Authority. But they treat the Public with some disingenuity, if they would overbear the judgement of others by that Authority, which as it appears from their own practice, hath had so little influence upon themselves. They chuse their own sentiments, as inclination or passion directs; and then desire us quietly to rest upon the Authority of Sir *Isaac*; tho' one of these has robb'd him of his *Attraction*, the other of his *Medium*; and thus between them both, they have left us nothing to follow."

149. "If the learned were but once persuaded, that God doth govern the natural world by a delegation of material Instruments, which seems to have been *one* of the opinions of Sir *Isaac*, at least it was an opinion held by Mr. *Maclaurin* in his name; and could be brought to see any errors in the doctrine of resistance; something, I am convinced, might yet be done, either in this, or the succeeding age, to render

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natural Knowledge more ſerviceable to People of all Claſſes than it is at preſent; chiefly, becauſe the enquirers of theſe times would no longer have their hands tied up by an imaginary infallibility in thoſe who have gone before them; the admitting of which, has always been attended with fatal effects: They might then reject ſuch principles as are manifeſtly falſe, and *put a ſtop to their enquiries*, and take advantage of the reſt in common."

150. "It is ſtill believed however by very many, either that matter, tho' inert, is endued with active qualities; or that the influence of the Deity is immediate in the production of all natural effects. By the former of theſe poſitions, we allow to dead matter a power that is denied even to God himſelf*: By the latter of them, we are directed to read nature backward; to begin where we ought to have ended; and in ſupport of ſuch procedure, are obliged to annihilate the far greater part of the Creation. I ſhall therefore go on to examine, how far theſe poſitions are ſupported by mathematical evidence."

* Omnipræſens eſt non per *virtutem* ſolam, ſed etiam per *ſubſtantiam*: Nam virtus ſine ſubſtantiâ ſubſiſtere non poteſt. *Newt. Princip.* ſchol. gen.

CHAP. X. PART III.

SECTION 151.

The Attraction of Gravity, *understood as an* universal property *or* quality *in the parts of Matter, hath receiv'd no proof from* Geometry.

"WE have been assured from every quarter, that the modern doctrine of physical Causes has all the evidence that can be desired from Experiment, and is abundantly confirmed by the most strict mathematical Reasoning. That this doctrine is deduced analytically from observation; then applied synthetically to the explication of the various Phænomena: And its impregnability in these respects has been boasted of, I will not say insolently, but confidently enough I am sure, by all its admirers great and small, from the learned, who think it rests on the firm basis of Geometry itself, down to our mere *English* Mathematicians, who declare it as their opinion, that "*never a Philosopher before* Newton "*ever took the method that he did——that it is* "*a mere joke to talk of a new Philosophy——* "*And that in these umhappy days of ignorance* "*and avarice,* Minerva *has given place to* Pluto," meaning *Plutus* *."

* See the Preface to *Emerson*'s treatise on *Mecha-*

152.

152. "Theſe pretenſions, whether of the learned or unlearned, deſerve a ſerious examination. Experiment is nothing leſs than matter of fact, which if not miſrepreſented, is the beſt ſort of argument in the world: And a *mathematical* concluſion, if deduced from real *data*, is not eaſily overthrown. Something has already been ſaid of mathematical evidence, in the former part of this Treatiſe; therefore I have the leſs to ſay of it in this place. And indeed, very little need be ſaid, if the Theory of reſiſtance be a fallacy, as I have fully proved it to be; for *that* is the thing generally aimed at by thoſe, who ſpeak of mathematical demonſtrations. It may nevertheleſs be uſeful to remark, that no phyſical Principles whatever can poſſibly be collected from Geometry. Every particular Science hath Principles peculiar to itſelf, and independent of every other. No example can be given of the contrary, within the whole circle of the Sciences. How abſurd would it appear, if we were told of the muſical Principles of Phyſic, the medicinal Principles of the civil Law, the grammatical Principles of Aſtronomy? *&c.* And mathematical Principles of natural Philoſophy, if *phyſical Cauſes* are ſuppoſed to be included, will be equally unnatural;

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nics. The Book is very ingenious and uſeful in its way, and the Author appears to underſtand his Subject; but when he decides thus magiſterially upon Philoſophy in general, it is — *ſutor ultrà crepidam.*

as the moſt ſkilful Mathematicians have been ready enough to confeſs. " Geometry ſays Mr. *Maclaurin*, can be of little uſe in natural Philoſophy, till *data* are collected to build upon *." Theſe data, I preſume, are to be obtained from natural Philoſophy, as a Science circumſcribed within its own proper bounds. A method of inveſtigation, ſtrictly phyſical, ſhould firſt be ſubmitted to; and the reſult of that be examined and ſettled, prior to all that can be done in Geometry; the application of which, may be of excellent uſe to illuſtrate and adapt to particular caſes what hath gone before; but will add neither demonſtration nor confirmation to it. For a Geometrician can work with imaginary or hypothetical forces as well as with real ones; the operation will go on as ſmoothly, and the concluſion come out as readily in one caſe as in the other. No Man ſeems to have been better perſuaded of this, than Sir *Iſaac Newton* himſelf. His followers indeed will aſſure us, he has undeniably proved one ſpecies of attraction to be diffuſed thro' the whole planetary Syſtem †. But the Author himſelf knew better. He declares more than once, that the Principles, laid down by him in his demonſtrative work, were not phyſical but purely mathematical ‡, as the *Title* implies: And with regard to Gravity or Attraction in particular, he

* P. 35. † *Friend*, Chym. Lect. p. 180.
‡ P. 356.

is ſo far from pretending to have demonſtrated the exiſtence of any real phyſical Cauſe under that term, that his definition of it is ſo looſe, as to leave us quite at liberty about it. We may take it as a drawing, an impulſe, or a tendency of any kind toward a center. When he conſider'd it phyſically, he thought a Medium might ſuffice to *impel* Bodies, and anſwer all the purpoſes of that attraction, which as it ſtands in his Principia, is a cauſe barely hypothetical. Should it be imagined, that attraction, as a cauſe, power, or principle, had been eſtabliſhed by demonſtration; the Author will be ſet in a very diſadvantageous light, who could firſt *demonſtrate* attraction, and then *enquire* about it."

153. "But there is one circumſtance that will put this whole affair out of doubt. It is well known, that the attraction ſuppoſed in the Principia, is mutual between all Bodies whatſoever. If the Earth attracts the Moon, the Moon in its turn attracts the Earth; if the Sun attracts the Planets, the Planets alſo attract the Sun; and this attraction always follows the proportion of the quantities of matter in the attracting Bodies. As a neceſſary conſequence of this, the Sun will be perpetually ſhifting its place, and be moved ſometimes to this ſide of the common center of Gravity, ſometimes to that, as he happens to be influenced by a different ſituation of the Planets *."

* Sol, pro vario &c. *Princip.* p. 374.

154.

154. " Now I beg leave to compare this with what is ſaid of an ætherial Medium in the Treatiſe of Optics. This Medium is ſuppoſed to be *rareſt* at the Body of the Sun; but to increaſe in denſity through all the diſtances from the Sun to Saturn and beyond; and that it may ſuffice to *impel* Bodies from the denſer parts of the Medium toward the rarer, with all that power which we call Gravity *. All this is very juſt: The preſſure of ſuch a Medium will undoubtedly be greateſt on *that ſide* of the Planets, which is turned *from* the Sun; and all Bodies will naturally be carried to that ſide, where the preſſure is weakeſt; that is, *toward* the Sun. But what is become of the Sun's *mutual Gravity* in ſuch a caſe? For if he gravitates toward the Planets, we muſt contradict this mechanical rule, and ſay, Bodies will be impelled from the rarer parts of the Medium toward the denſer; without which, the Sun, being already in the rareſt part, muſt for ever be at reſt. Sir *Iſaac* either did ſee this conſequence, or he did not. That he did not ſee the plaineſt conſequences of his own reaſoning, few will be ready to admit: If he did, he gave up mutual gravity to all intents and purpoſes; but this he never could have done, had he thought it to have been mathematically demonſtrated."

155. " I hope I ſhall not be miſunderſtood in this affair. It appears to me, that Gravity is

* Q. 21.

no

no property of Matter, becaufe it is not univerfal; and I have compared fome paffages, to fhew it was not univerfal in the opinion of Sir *Ifaac* himfelf; provided only he faw the confequence of his own reafoning, which will hardly be difputed. But while I am perfuaded, that the Sun neither does, nor can poffibly, gravitate toward the Planets, for the very reafon given by Sir *Ifaac Newton*, I am far from denying that the Planets tend toward the Sun, and toward each other: It is highly reafonable, with fome proper reftrictions, they fhould do fo; and experience, I believe, will convince any Aftronomer of the fact. As the world ftands indebted to the Genius of that great Geometrician for this difcovery, let the learned obtain from it what light they can in afcertaining the Phænomena, and let him have all the honour of it. But never let it be a pretence for faddling us with occult powers in folid matter; if his followers make that ufe of it, they will gain no credit to their Mafter in the end; and hitherto they have gained but little to themfelves by it, as it muft have appeared from what hath been faid; in all which, I hope there hath been on my part no mixture of envy or prejudice; unlefs matters of fact, and plain argumentation, are fo to be interpreted."

156. "We are to conclude then, that the Attraction of Gravity, underftood as an univerfal property of matter, is void of all geometrical evidence. If Sir *Ifaac Newton* hath left this af-

fair undecided, no other Geometrician, of this age or the next, is like to supply his defects: And yet every smatterer almost in natural Philosophy is persuaded he can make it out against all opposition. The ground and reason of which mistake I apprehend to be this; that many of our Geometricians, ambitious of dictating to us about the causes and first springs of nature, while their art can reach only to the *measure* of some of its *effects*, have not been careful to distinguish, how far a mathematical conclusion will extend, and how far not. Hypothetical forces or real ones, as it was observed above, will equally afford matter for an Astronomer to work upon *. For example, if the Moon, as she moves in her orbit, is imagined to be influenced by forces acting in lines which tend toward the centers of the Earth and Sun; then the different inclinations of her orbit to the ecliptic, the irregular motion of her nodes, her retardation about the quadratures, her acceleration about the conjunctions &c. may follow by the rules of Geometry. Upon these principles, Sir *Isaac Newton* is universally allowed to have accounted for the lunar irregularities with great sagacity, and, as an Astronomer, to have left that matter in a much better state than he found it; though it is not yet perfected. But

* Neque necesse putant, ut hypotheses istæ veræ sint, imo ne verisimiles quidem, sed sufficit hoc unum, ut calculum observationibus congruentem exhibeant. *Horrocc.* Op. Post. 179.

what

what theſe forces are in ſpecial, and in what manner they act; whether as an active immaterial virtue, exerted through a void ſpace, *from* the centers of the Earth and Sun; or as a preſſure of ſome ætherial Medium acting in lines *toward* thoſe centers; none of his reaſonings have determined for us. So far from it, that we find his Principia inclining to one ſide, and his phyſical Queries to the other. And I may appeal to the judgement of any ingenuous Man, ſufficiently verſed in mathematical ſtudies, whether the Phænomena above-mentioned may not ariſe from a preſſure *behind*, as well as from an attraction *before*; and whether Sir *Iſaac*'s geometrical reaſoning will not be as concluſive in the one caſe as in the other? How comes it then to have been publiſhed to the world, that "one ſpecies of Attraction hath been undeniably proved to be diffuſed through the whole planetary Syſtem?" This having been no more proved by any of his arguments, than that one ſpecies of *impulſe* or *preſſure* is diffuſed thro' the whole planetary Syſtem; and for the truth of this, I may refer to the *definition*, where the terms *attraction* and *impulſe* are taken indifferently, and are to be ſo taken throughout the the whole Book; otherwiſe this can anſwer no purpoſe as a *definition*. That ſome force prevails, and in ſuch particular directions, is capable of demonſtration: But the reaſoning and obſervation, which only prove the exiſtence of ſome force in general, will never demonſtrate

that of Attraction to be the force in particular. So that nothing farther need be said in this way. Let us now go on to Experiment."

157. "No experience has hitherto shewn us, that what is called the *attractive force* of the Sun and Planets, is answerable to their quantities of solid matter. Their bulk, as computed from their respective distances and apparent diameters, is far from yielding a proportion of Gravity so uniform as might have been expected. Gravity toward the Earth proves to be much greater in proportion to the bulk of the Earth, than Gravity toward the Sun, or any of the primary Planets. This seems to be a great difficulty in the hypothesis of Gravity. But how easily is it reconciled, if we are allow'd to alter the *density* of the heavenly Bodies, and by this means bring their quantities of matter to an agreement with the hypothesis? The *Fiat* of a favourite Philosopher can so reduce the density of the solid matter in the Body of the Sun, that the density of the Earth shall be *four times* greater; and then the attractive power of the Sun shall exactly answer to his quantity of solid matter: And the same liberty must be taken with the other great Bodies of the solar System. Their density must be accommodated to their attractive powers: Then if their attractive powers be taken for granted, their densities will pass for a *discovery*. Thus great Men amuse themselves and the world by arguing in a circle, or proving the truth of a proposition

by

by the conclusions they have drawn from it; for unless you admit of this density, which arbitrarily, and without any observations to support it, is accommodated to the hypothesis of Gravity; that hypothesis will labour under a disagreement with observation."

158. "That there may be some shew of experience however in all this, it is intimated that the Sun must needs be rarer than the Earth, because of the immense heat of his Body*. But the Planet *Jupiter*, whose Body must be exceedingly colder than that of the Earth, appears from his attractive Power upon his Satellites† to be much rarer than the Sun, and *Saturn* rarer still; which circumstances are very unpromising; and if Gravity be admitted here as the sole agent, we are conducted to a sort of Philosophy, that blows hot and cold, against all reason and experiment. *Des-Cartes* was of opinion, that the density of the Planets must naturally increase as they are more remote from the Sun: And surely this is more reasonable than the contrary; it being an observation, to the best of our knowledge universally true, that Bodies are rarefied by heat, and condensed by cold; the seeming rarefaction of ice not excepted."

* Nam per ingentem suum calorem sol rarescit. *Princip.* p. 372. † The method Sir *Isaac* made use of to investigate this mathematically, is laid down in a manner as easy as the thing is capable of by Dr. *John Clarke*, in his *demonstration* of Sir *Isaac New-*

159. "Gravity, it has been said*, is the "quality of all Bodies on which any expe- "riments have been made;" and that as Bodies near the Earth gravitate toward the Earth, so all "Bodies in the Heavens gravitate toward "the Sun †." But if we believe this, there is an end of all experience: For, supposing this to be true, not one atom of light could ever come to us from the Body of the Sun. Who would undertake to prove, that the Air of our Atmosphere did gravitate toward the Earth, if it were incessantly flying off from it toward the Moon and the other Planets? This is the case with the atmosphere of the Sun. A flood of matter is sent off every moment with immense rapidity from his orb, in a direction opposite to that of gravitating Bodies; and in so large a quantity, that no space however small could be assumed within the whole solar System, where the point of a needle could be opposed to the Sun, without stopping some thousands or millions of the particles thus sent from him. So long as the Sun shines, a Man must do violence to his own senses, if he can believe a centripetal tendency to be the quality of all matter; when the matter, void of that quality, is in all appearance as far superior in quantity to the matter possessed of it, as the whole Globe of the

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ton's Principles of Philosophy. 8vo. p. 301. See also Mr. Maclaurin's account &c. p. 2[illegible]5, &c. * Princip. Lib. 3. prop. 7. Cor. 2. † Ibid. p. 403.

Earth

Earth to an ordinary Mountain. But be the quantity great or ſmall, if the ſolar light is only allowed to be a material ſubſtance, the concluſion will hold good."

160. "This grand objection to the gravitarian hypotheſis has never been ſtated, or directly replied to, in the philoſophical Works of Sir *Iſaac Newton*; and is generally paſſed over in ſilence by all his proſelytes; though there is nothing more worthy of admiration, nor more beneficial to mankind, in the whole œconomy of created things, than the conſtant emiſſion of light from the Sun."

161. "There are indeed two arguments, if they can be called ſuch, by which our attention ſeems to be tacitly called off from this difficulty. They are certainly of no great importance in themſelves; but by paſſing through the Pen of Sir *Iſaac Newton*, they are render'd too conſiderable to be neglected. The firſt is a poſition borrowed from *Ariſtotle* and *Des-Cartes*, that "matter differs from matter only in form, retaining all other properties in common *." But this cannot be admitted without ſome proof; becauſe it is the very point in queſtion. That gravity is one of thoſe properties which are retained in common, though the form of the matter be different, is an article, which has never yet been proved; and I humbly think, never will be, the propagation of light from the Sun being a poſitive inſtance to the contrary.

* P. 368.

It

It would be weak to oppose an unsupported assertion, a mere logical subtilty, to so plain and important a matter of fact; the conclusion from which is so visible, that nothing but art or prejudice can avoid it: It depends not on *words*, but on the visible constitution of *things*, and offers itself to the common observation of all Men in the great out-lines of nature."

162. "Another method of evading this difficulty, is, to represent the element of Fire, or matter of light, as a mere nothing; a substance, which may occupy a space in so singular a manner, as to leave it *empty**: And it seems to be questioned, whether a Reader will recollect that there is such a fluid as that of light in the solar System †. Where we might have hoped to receive from so masterly an hand some instruction concerning the nature and uses of this wonderful fluid, we are amused with a long account of transmutations, unnatural and romantic, founded on an experiment of Mr. *Boyle*, in which he thought he had obtained fixed Earth from Water. But *Boerhaave* ‡ carefully examined this, and found it to be a mistake. Hence however Sir *Isaac* inferred, that as Water is turned into Earth, so gross Bodies are turned into light, and light into bodies ||;

* Empty celestial spaces. Opt. Q. 21. † Si fortè vapores longe tenuissimos, et trajectos Lucis radios excipias. p. 328. *Princ.* ‡ See *Shaw*'s Edition of *Boerhaave*'s Chymistry. V. I. p. 471.

|| Mr. *Boyle* has an hydrostatical experiment to

though

though by a principle adopted on another occasion, all this is render'd very improbable, if not altogether impoſſible. He is of opinion, that the primitive particles of Bodies will "compoſe "bodies of one and the ſame nature and texture in all ages *;" with which all tranſmutations whatſoever are inconſiſtent. In ſhort, the matter of light ſeems to have been but a troubleſome gueſt in the mathematic Philoſophy, though the Author of it was indebted to it for the beſt and moſt durable part of his reputation. And long may it laſt; it is no intereſt of mine to wiſh that the fickleneſs and inconſtancy of mankind may ever deprive him of it. He aſks "Is not fire a body heated ſo hot, as "to emit light copiouſly? For what elſe is a "red-hot iron than fire †?" Let us anſwer this, by putting a like queſtion concerning the element of water. "Is not water a body wetted "ſo much, as to wet every thing elſe copiouſ-"ly? For what elſe is a wet ſponge than wa-"ter?" In this latter example every Perſon will allow the ſponge to be a diſtinct body from the water, containing that element in its vacuities. Now fire is as truly an object of ſenſe as water; and hath as many properties to diſtinguiſh it as a fluid. What can a red-hot iron be therefore, but *iron* and *fire*, that is, iron

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prove, that when the weight of any metal is increaſed by fire, the fire is not turned into metal.

* Opt. 376. † Qu. 9.

with

[illegible]

Effect, [illegible] —— And [illegible] hard for Princi-ple, [illegible] frequently the case, and many [illegible] that a variety of things appear to be performed by Impulse, which were for-

merly

merly attributed to Attraction; yet ſo tenacious are they of the favourite term, as to inſiſt that ſince the ſame effect is produced, and the ſame thing meant, it is indifferent whether we call it attraction or impulſe, and therefore upbraid thoſe with perverſeneſs who are of different ſentiments with them, as diſputing for what at moſt is no more than the meaning of a Term.

165. But this is ſuch an unparallelled irrational ſtretch as muſt be deem'd unpardonable, were our Language more barren than even the Hebrew itſelf: Whereas, to ſay the truth, the Engliſh Tongue is ſo far from being chargeable with ſuch ſterility, that, if poſſible, it is too fertile: The learned Dr. *Johnſon's* obſervation on our Language is, "that a ſtop ought to be put to the growth of it; for if it were to continue to increaſe its luxuriancy, and to be ſtill more and more enriched with words, it would at length become like the Lady who was borne down by the weight of her own Jewels." But to return.

166. Since the component parts of the electrical fluid are in an elaſtic and repelling ſtate, the effects of the experiments can therefore never be rationally accounted for by attraction; this was my reaſon for conſidering them in a light ſo different from moſt other Electricians. —— But the principal cauſe of the many ambiguities attending Electricity, appears to proceed from the want of a better acquaintance with the Air; I deſire therefore briefly to re-

fume the fame fubject fo far as to enquire what conceptions were formed of it, before it was illuminated by the difcovery of the *Force* of the electrical fluid by Profeffor *Mufchenbroek*, which I call the *Æra* of Electricity.

167. By means of particular operations in Chymiftry, and fome other experiments after the invention of the Air-pump, it was difcover'd that Air might be very plentifully obtained from many different Bodies, which before *that* period were never thought capable of containing it; but as fuch an active Æther or pure Air, which Sir *Ifaac Newton* had pointed out, was not only excluded by many of his Difciples from the pores of grofs Bodies, but its very exiftence alfo denied; the accounting for the production of Air from fuch denfe Bodies as were impervious to the common Air, was attended with the utmoft difficulties. The only remaining fubterfuge, as it fhould feem, was, to attempt to prove, that the Elements were tranfmutable into each other, and that a confiderable part of grofs Bodies was convertible into Air, and which confequently was a principal ingredient of their firft compofition.

168. Amongft the defenders of that doctrine the renowned Dr. *Hales*, in his vegetable Statics, has diftinguifhed himfelf, and feems to have made the moft of it of any one, and to have gained over the greateft number of profelytes to fuch an unnatural opinion.

169. He, by the force and action of heat, diftil-

diftillation, fermentation, effervefcences of acids with alcalies, *&c.* fo tortured grofs Bodies with experiments of various forts, as to volatilize a very confiderable part of, and, as he thought, to convert them into a quite different element, i. e. into *Air*, which naturally inclined him to believe that Air was no fmall part of the fubftance of Bodies.

170. But if fuch a doctrine were allowed, what confufion and inconfiftencies would be diffufed through every branch of natural Philofophy? Inftead of clearing it of ambiguities, what a multiplied number of them would be neceffarily introduced thereby? If that were found reafoning, it would be no difficult tafk in the next place, to prove that the number of elements were reducible to one only: For if we could fo eafily metamorphofe grofs Bodies, folids and fluids, into real Air, confequently they muft be compofed of Air; and as for Fire, it was denied to exift long before.

171. But if we allowed of a probability of the truth of a tranfmutation of the elements into each other, muft we not then be conftrained to allow that Philofophy is in a moft fluctuating condition? *e. gr.* The current opinion is, that grofs Bodies are convertible into Fire, whereas Dr. *Hales* can as eafily prove that they are convertible into common Air.——A few of this learned *Doctor*'s Experiments, together with his manner of Reafoning thereon, may not be unacceptable to the inquifitive Reader.

CHAP. XI. PART III.

SECTION 172.

A Specimen of Dr. Hales' *Method of converting* groſs Bodies *into* Air *by means of Diſtillation*, &c. *With ſome Remarks of the* Author *thereupon.*

VEGETABLE STATICS, Vol. 1ſt.
EXPERIMENT LV.

"FROM half a cubic inch, or 135 grains of heart of *Oak*, freſh cut from the growing tree, were generated 108 cubic inches of Air, i. e. a quantity equal to 216 times the bulk of the piece of *Oak*; its weight was above thirty grains, ¼ part of the weight of 135 grains of *Oak*. I took a like quantity of thin ſhavings from the ſame piece of *Oak*, and dried them gently at ſome diſtance from a fire for 24 hours, in which time 44 grains weight of moiſture had evaporated; which being deducted from the 135 grains, there remain 91 grains for the ſolid part of the *Oak*: Then the 30 grains of Air will be ⅓ of the weight of the ſolid part of the *Oak*." ——

173. "Eleven days after this Air was *made*, I put a live Sparrow into it, which died inſtantly."

EXPE-

EXPERIMENT 57.

174. "From a cubic inch, or 318 grains of *Peas*, were generated 396 cubic inches of Air, or 113 grains, i. e. something more than ⅓ of the weight of the *peas*."

175. "Nine days after this Air was made, I lifted the inverted mouth of the receiver which contained it, out of the water, and put a lighted candle under it, upon which it instantly flashed: Then I immediately immersed the mouth of the receiver in the water, to extinguish the flame; This I repeated 8 or 10 times, and it as often flashed, after which it ceased, all the sulphureous spirit being burnt."

176. "It was the same with Air of distilled *Oyster-shell* and *Amber*, and with new distilled Air of *Peas* and *Bees-wax*. I found it the same also with another like quantity of Air of *Peas*; notwithstanding I washed that Air no less than eleven times, by pouring it so often under water, upwards, out of the containing vessel, into another inverted receiver full of water."

Experiment 87.

177. "Twenty six cubic inches of *Apples* being mashed *August* 10. they did in 13 days generate 968 cubic inches of Air, a quantity equal to 48 times their bulk; after which they did in three or four days resorb a quantity equal to their bulk, notwithstanding it was very hot weather; after which they were stationary, neither resorbing nor generating Air in many days."

178.

Experiment 89. p. 213.

178. Speaking of the ſame experiment. He adds, "This Air, when in the Apples, muſt be compreſſed into leſs than a forty eighth part of the ſpace it takes up, when freed from them, and it will conſequently be 48 times more denſe; and ſince the force of compreſſed Air is proportional to its denſity, that force which compreſſes and confines this Air in the Apples, muſt be equal to the weight of 48 of our Atmoſpheres, when the Mercury in the Barometer ſtands at fair, that is 30 inches high."

179. "Now a cubic inch of Mercury weighing 3580 grains, thirty cubic inches (which is equal to the weight of our atmoſphere on an area of a cubic inch) will weigh 15 pounds, 5 ounces, 215 grains; and 48 of them will weigh above 836 pounds; which is therefore equal to the force with which an inch ſquare of the ſurface of the Apple would compreſs the Air, ſuppoſing there were no other ſubſtance but Air in the Apple: And if we take the ſurface of an Apple at 16 ſquare inches, then the whole force with which that ſurface would compreſs the included Air, would be 13383 pounds. And ſince action and re-action are equal, this would be the force, with which the Air in the Apple would endeavour to expand itſelf, if it were there in an elaſtic and ſtrongly compreſſed ſtate: But ſo great an expanſive force in an Apple would certainly rend the ſubſtance of it with a ſtrong exploſion, eſpecially

cially

cially when that force was increafed by the vigorous influence of the Sun's warmth."

180. To convince Dr. *Hales* that the Air contained in an Apple is in an elaftic and compreffed ftate, notwithftanding it does not rend the Apple in the manner he fuppofed, I fhall tranfcribe an Experiment of the ingenious Mr. *Martin*, with an Apple juft gathered from the tree.

181. "I connect it (faith he) with a piece of brafs and fink it to the bottom, in a glafs of clear water, having firft made a few holes in it with a pin—— Then I cover it with a glafs, and as I begin to exhauft, you fee the Air arife from the different parts of the Apple, but particularly from the holes made with the pin.— As I further proceed, you fee the Air rifing from the pores of the Apple in many fenfible ftreams. —— As the Air is ftill farther rarefied, the ftreams are more and more numerous, and the quantity of Air fo great, as to make a perfect ebullition on the top of the water."

182. "If the Vacuum remains for any time, you will fee the bubbles and ftreams of Air continue fo, a long time; and if you look at the gage, you will fee the Mercury fink in proportion to the Air produced from the Apple, and this as often as the Experiment is repeated.—— At laft I turn the Vent-fcrew, and the Air difappears at once." *See* his *Gentleman* and *Lady's* Philofophy, p. 381.

183. Do not the effects of this experiment

moft

moſt evidently prove that the Air in an Apple is not there in a fixed, but in an elaſtic ſtate; and that the only cauſe which prevents it from eſcaping out of it is the repelling ſpring and preſſure of the circumambient Air, ſince that was no ſooner weaken'd, but it immediately began to eſcape out of it, in a great number of viſible ſtreams, and at length, with ſuch violence, as to cauſe an ebullition of the water? So great is the propenſity of the Air in the Apple to maintain the equilibrium; and this is ſtill farther confirmed by ſeeing the mercury ſubſide in the gage, and that no ſooner was the Vent-ſcrew turned to let in the common Air, but thoſe ſtreams of Air immediately diſappeared.

184. The Dr. at the latter end of the 89th Experiment of his firſt Volume repeats the 55th Experiment, concerning the half cubic inch of oak—— "There aroſe, he ſays, from a piece of heart of oak 216 times its bulk of Air: Now 216 cubic inches of Air, compreſſed into the ſpace of one cubic inch, would, if it continued there in an elaſtic ſtate, preſs againſt one ſide of the cubic inch with an expanſive force equal to 3393 pounds weight, ſuppoſing there were no other ſubſtance but Air contained in it; and it would preſs againſt the ſix ſides of the cube, with a force equal to 20350 pounds, a force ſufficient to rend the Oak with a vaſt exploſion: It is very reaſonable therefore to conclude, that moſt of theſe

now active particles of the new generated Air, were in a fixed ſtate in the Apple and Oak before they were rouſed, and put into an active repelling ſtate, by fermentation and fire."

185. "And if to the air thus generated from a veſſel of any vegetable liquor by fermentation, we add the air that might afterwards be obtained from it by heat or diſtillation; and to that alſo the vaſt quantity of air, which by Experiment 73 is found to be contained in its Tartar, which adheres to the ſides of the veſſel; it would by this means be found that Air makes *a very conſiderable part* of the *ſubſtance of Vegetables*, as well as of *Animals*." *Veg. Stat.* V. I. p. 216. 3d. Ed.

186. The *Doctor's* rule of judging what quantity of Air was in the pulp of the Apple before it was fermented, was by finding how much ſpace the ſame air occupied after 13 days fermentation.——Since the air did not then rend it with a ſtrong exploſion, he thought that to be a ſure proof of its being in an unelaſtic fixed ſtate while it was in the Apple; but Mr. *Martin's* experiment on the Air-pump was a full proof of the contrary, and therefore proved his concluſions to be falſe.——*N. B.* He endeavours to ſhew that this artificial Air took up no more room after it was heated than before.

187. "That I might be well aſſured, ſays he, that no part of the new air which was produced in diſtillation of bodies, aroſe either from the greatly heated air in the retorts, or from the

fubftance of the heated retorts, I firft gave a red hot heat both to an empty glafs retort, and alfo to an iron retort made of a mufket barrel; when all was cold, I found the air *took up no more room than before it was heated:* Whence I was affured, that no air arofe, either from the fubftance of the retorts, or from the heated air." p. 172. 173.

188. If it fhould be afked, how it comes to pafs that fo great a quantity of elaftic air is generated in Dr. *Hales'* experiments after the bodies were diffolved by fermentation, diftillation, *&c.* if a confiderable part of the grofs bodies themfelves were not compofed of air, fince many of them were fo denfe and compact as not to admit the air into their pores? I anfwer: That to clear up this matter, it feems neceffary to confider, firft, the definition of common air.

189. "In Air is conceived two parts, the one " more grofs which is raifed and carried off from " the bodies of this terraqueous mafs: The " other a fine fubtile fpirit, by means whereof " the former is render'd volatile and elaftic. " Together they compofe a medium, whofe " elafticity is lefs than that of pure æther, fire, " or fpirit, in proportion to the quantity of falts, " vapours, and heterogeneous particles contain- " ed therein." Secondly, Sir *Ifaac Newton's* difcovery of a fubtile fpirit or æther which lies hid in the pores of all grofs bodies, mentioned in that portentous paragraph with which he concludes his Principia; the truth of which is

ſo manifeſtly verified and confirmed by means of electrical Experiments.

190. The ſubtile Spirit or pure Air, contained in the pores of thoſe bodies before their diſſolution, do, when analyſed into its firſt principles, naturally mix and incorporate with thoſe minute particles of groſs matter, in a ſimilar manner, as when in their original ſtate, and thus an artificial Air is generated, as elaſtic and ponderous, and in moſt other reſpects, the ſame as common air, conſequently as permanent as that. —— The eaſier the body is diſſolved and the more freely the terreſtrial corpuſcles riſe in the diſtillation, the greater is the quantity of *what* he calls the *new generated Air*.

191. This ſeems to be the only reaſon why ſo great a quantity was generated when the human calculus was diſtilled; one half of the weight of the ſtone was, by this means, volatilized and incorporated with the contained æther.

192. This appears to be confirmed by conſidering a quite different and contrary deception, which happen'd when the maſs to be analyſed contained almoſt the greateſt quantity of the pure elementary air or ſpirit, and very little groſs matter.

193. In Experiment 66. Vol. I. Dr. *Hales* found very little air in 54 cubic inches of brandy: Had it been a highly rectified ſpirit, he would have found none; all would have eſcaped, there being no groſs matter to riſe and

incorporate with it to prevent it.

194. Hence it comes to paſs that when there is contained in the maſs to be analyſed, the greateſt quantity of all, of the pure ſubtile elementary Air, that no artificial Air can then be formed. Rectified ſpirit of Wine ſeems, as it were, the pure Air or Fire, in a liquid form.

195. What evidently proves the ſpirits of Wine to be much more elaſtic than other liquids, notwithſtanding the *Doctor* could obtain no elaſtic Air from them, is another experiment of the ingenious Mr. *Martin*, where he ſhews, that if a jar of the ſpirits be put under the receiver of an Air-pump and the air exhauſted, the particles of the ſpirits expand to ſuch a degree as to cauſe a perfect ebullition as if boiling over the fire. *Gentleman* and *Lady*'s Philoſophy, Vol. I. p. 377.

196. Towards the latter end of the *Doctor*'s 89th Experiment, Vol. I. p. 215. he ſays, "It "is very reaſonable to conclude that moſt of "theſe now active particles of the new gene-"rated air, were in a fixed ſtate in the Apple "and the Oak before they were rouſed, and "put into an active repelling ſtate, by fermen-"tation and fire."

197. Is it not ſtrange that a Man of the *Doctor*'s penetration could perſuade himſelf that Air when ſo violently compreſſed as to take up but a 48th part of the ſpace which it contained when in its natural ſtate, would require ſo much heat or fermentation to rouſe it (as he

ſays)

ſays) to an active repelling ſtate? —— But he ſeems to have overlooked a much more remarkable experiment than that of the maſhed Apples, viz. That of the cubic inch of Peas, from which, he informs us, were generated 396 cubic inches of Air.

198. As the Air when freed from the maſhed Apples therefore occupied 48 times more ſpace than when it remained in it; the *Doctor* avers that ſuppoſing it elaſtic, while in the Apple, it was equal to the ſpring and preſſure of 48 atmoſpheres; then conſequently, by the ſame rule, the Air of the Peas, before it was freed from them, was equal to the ſpring and preſſure of 396 Atmoſpheres, ſince it occupied ſo many times the ſpace of the bulk of the peas, after it was freed from them; and a much greater yet from the calculus humanus, *that* air occupying 645 times the ſpace of the calculus, more than 13 times 48. See Vol. II. Exp. 1ſt. p. 191.

199. But as Nature is never known to act in vain, a queſtion would naturally ariſe, What reaſon can be aſſigned for diveſting ſo prodigious a quantity of air of its elaſticity, and what uſeful purpoſe could the crouding of it into a 645th part of its natural ſpace ſerve? (which was the caſe in the air produced from the hu-human calculus) and ſhould, notwithſtanding that, *require ſo great a heat to rouſe it to an elaſtic ſtate.*

200. To ſay "*This muſt needs be owing to the direction of an All-wiſe Being*, would be ſaying nothing to the purpoſe, ſince this is true of all other operations of nature; beſides, that would be too much like begging the queſtion which ought to be proved, *viz.* that there is ſuch a double capacity, as is ſuppoſed, of changing from a ſtrongly attracting, to a vaſtly repelling ſtate, and *vice verſâ.*

CHAP. XII. PART III.

SECTION 201.

The Author's *Account of the Effects of Dr.* Hales' *Experiments.*

THAT I may keep clear of the foul and odious imputation of pulling down freely, where I am not able to build up ſomething in its place that may appear more rational, I ſhall here conſider the effects of the *Doctor*'s Experiments in a different light, and try if they are not capable of being render'd more clear; for that will be dealing with him in the ſame rational manner which I ſhould hope to be dealt with myſelf by

by any one who ſhall attempt to pull down the Fabrick which I am now endeavouring to erect; that is, not only by pointing out difficulties, but by ſhewing a more conciſe, and eligible method of ſolving them than I have done: By ſuch a plain and candid way of dealing, they will leave no room for ill natured reflections, ſuch as, ONE FOOL *may ſoon aſk more Queſtions than* TEN WISE MEN *can ever be able to ſolve*, and the like.

202. Suffer me but to compare Dr. *Hales*' bodies while diſſolving, with thoſe operations of nature which are particularly pointed out in the 4th Head of my Theory, Part I. Sect. 50. and then the otherwiſe ſeeming paradoxes and difficulties will ſoon vaniſh.

203. There we ſhall find *that the primary Air or exquiſitely ſubtile and elaſtic Æther when in its natural ſtate, by being intimately mixed and incorporated with the moſt minute particles or effluvia of the groſs matter, forms a ſecondary Air, ſimilar in its chief properties with the primary, ſuch as, in its rarity, ſubtilty, and permanent elaſticity, tho' in a much leſs degree.* And it muſt be confeſſed, the *Doctor*'s artificial proceſs in Chymiſtry, is a lively repreſentation of the above-mentioned grand proceſs of Nature.

204. But ſince Sir *Iſaac Newton*'s aſſertion of a pure Air, ſubtile Medium, or Spirit, in the pores of groſs Bodies, proves true, and is realized to our ſenſes, it becomes neceſſary to conſider

ſider Dr. *Hales'* Experiments in a different light, by which means they will appear much more conſiſtent with the reſt of Nature's Works.

205. His groſs Bodies by being tortured with heat, fermentation, efferveſcences of acids with alcalies, diſtillation, &c. may very well be conceived as analyſed and reduced to a ſtate approaching towards their primitive elements, or original atoms or corpuſcles. Secondly. Theſe being, I ſay, thus artificially reduced almoſt to their original chaotic ſtate, the pure Air or Æther, which before ſuch diſſolution lay concealed in their pores, is now at liberty and cloſing with the terreſtrial effluvia ariſing from thoſe bodies in their diſſolution, an artificial air is formed, permanent like the air of the atmoſphere, and in every other reſpect like it; excepting, that whereas the natural air is ſalutary to Animals, the *Doctor*'s artificial air is noxious and ſoon proves fatal to thoſe that are put into it.

206. Nor can there be much room to wonder, that the quantity of the ſubtile Æther contained in the pores of a groſs body whoſe dimenſions are only a cubical inch, ſhould afford ſo much greater a quantity of common air, if we do but conſider how many thouſand times more elaſtic and expanſive it is while it remains pure in the pores of denſe bodies than when it is reduced down to the ſtandard of common

air.

air*. So that as before obferved, what appeared fo much like an inexplicable myftery, *viz.* the great quantity of air in the *Doctor*'s experiments obtained from fo fmall a quantity of grofs matter is, by means of this confideration, render'd natural, and agreeable with the uniform workings of nature; and at the fame time greatly illuftrates the truth of what Sir *Ifaac* foretold many years ago, concerning an elaftic Medium in the pores of grofs bodies, which he alone difcover'd, even without the helps we now enjoy which confirm it. And I cannot help repeating it, that this Nation may with the greateft juftice, boaft of a Genius, that difcover'd what no mortal befides ever did, *viz.* firft, *A fubtile Æther in the pores of grofs Bodies*†, *and* fecondly, *That the fame fubtile Æther was endued with a rarity or thinnefs, and*

* According to Sir *Ifaac Newton*, the Æther when reduc'd to common Air, is then *decreas'd* in its Rarity and Elafticity in the proportion of 700000 to 1. and is confequently *increas'd* in its Quantity in the fame proportion; but Dr. *Hales* not having the fame evidence to prove the exiftence of fuch a fubtile elaftic Medium or pure Air in the pores of grofs Bodies as we now have, imagined that the Bodies themfelves fuffer'd a tranfmutation; not of the form only, but an actual tranfpeciation of the Elements themfelves, i. e. from a grofs and almoft inflexible ftate, to the moft flexible, and from inert terreftrial particles to active Air, and *vice verfâ.*

† *Princip.* p. 393.

at the ſame time with ſo great an elaſtic force, as to be almoſt beyond all human credibility *, without which diſcoveries, this active agent could never have been ſo ſatisfactorily explain'd by electrical experiments, ſince without them, a ſufficient light to proceed with had been wanting.

N. B. The greatneſs of the quantity of artificial air that the *Doctor* obtained from the pure interſtitial air contained in a cubical inch of groſs matter, is a ſtrong argument in favour of Sir *Iſaac*'s opinion concerning the greatneſs of the degree of proportion † between the vaſt rarity and elaſticity of the primary air, and that of the ſecondary or atmoſpherical air.

207. The *Doctor*, in order to confirm his Reaſoning, and render it the more plauſible, adds, " There are other inſtances in nature, " where the ſame particles are ſometimes in " an elaſtic, and at other times in a fixed ſtate: " Thus, ſays he, in the Experiments on Elec- " tricity, the ſame particles of Tinſel, Down, " *&c.* are, when approached by a well rubbed " glaſs Tube, ſometimes in a repulſive, i. e. " elaſtic ſtate, and ſometimes in an attractive " and cohering ſtate." *Veg. Stat.* Vol. II. 1ſt *Impreſſion*, p. 279 ‡.

* Optics, Quer. 21. † i. e. 700000 times.

‡ If the Reader recurs to Part I. of theſe Eſſays from *Section* 175 to 189. he will be convinced that Attraction has no ſhare in the above mention'd Inſtances in Electricity.

208.

208. From the enſuing intimation it appears, that the *Doctor* was ſo clearly perſuaded of the truth of his hypotheſis, [according to which, the Air was endued with ſuch a double capacity as to change backward and forward from an attracting to a repelling ſtate] that he ſeem'd to think all mankind would be of the ſame opinion: This being more than inſinuated in the following words.

209. " It will puzzle the *Epicureans* to give " a rational account how from a chaos, a mere " neceſſity of nature, and the caſual con- " courſe of atoms, ſo conſiderable a quantity " of matter *, as we find plentifully interſper- " ſed in animal, vegetable, and mineral Bodies, " ſhould be endued with this *double capacity*, " of changing, *pro re natâ*, from a ſtrongly at- " tracting *fixed* ſtate, to a permanently and " *vaſtly elaſtic* ſtate, and *vice verſâ*; this won- " derful property of it, which is ſo neceſſary " for carrying on the *conſtant regular* proceſſes " of *nature*, muſt needs be owing to the di- " rection of an All-wiſe Being." *Veg. Stat.* Impreſſ. 1ſt. Vol. II. p. 281.

210. But excluſive of ſuch a ſubtile elaſtic Fluid, ſince *conſtant regular nature* was never before known to act ſo *irregularly* in order to bring about her *proceſſes*, ſuch a conſideration alone is a ſufficient reaſon for rejecting the *Doctor*'s concluſions, and for our ſuſpicion that he had deceived even himſelf, in ſup-

* Air

poſing that ſuch a procedure was directed by an All-wiſe Being. Becauſe, that would appear like a much greater diſplay of infinite Power than of infinite Wiſdom, ſince we cannot eaſily conceive any one *wiſe* end that could be anſwered by it. And altho' Attraction and Impulſe in the ſame agent be not perhaps impoſſible for infinite Power to accompliſh; yet, as ſuch Power is always directed by infinite Wiſdom, that ſingle argument may convince us that Power would never have been ſo wonderfully diſplayed, unleſs wiſe ends had been as remarkably ſerved by it.

211. The ingenious Mr. *Martin* himſelf ſeem'd ſo deceiv'd with the *Doctor*'s Experiments and Arguments concerning the tranſmutation of the Elements into each other, that he exhibits an experiment which he thought proved the ſame thing ſo effectually, that it might in his opinion very well paſs for an *experimentum crucis* *.——Dr. *Black* wrote in favour of the ſame opinion.——Mr. *Macbride* ſeems to make great improvements in the ſame way; But if the *Doctor*'s opinion of a tranſmutation of the Elements into each other will not bear examination, neither can the reaſonings of any other which are founded on the ſame principles, be they ever ſo artfully put together.

212. Sir *Iſaac Newton*'s Arguments ſeem

* Mr. *Martin*'s Gentleman and Lady's Philoſ. p. 269.

much

much more conclusive as well as much more philosophical and agreeable to the uniform operations of nature, when he affirms that "No "ordinary Power is able to divide what God "himself made one in the first Creation.— "While the particles continue entire, they "may compose Bodies of one and the same "nature and texture in all ages. But should "they wear away, or break in pieces, the na- "ture of things depending on them, would be "changed. Water and Earth composed of old "worn particles and fragments of particles, "would not be of the same nature and texture "now, with Water and Earth composed of en- "tire particles, in the beginning *." If then no ordinary Power is able to divide what God made one: Much less can we at pleasure transpeciate the most inflexible, gross, inert particles, and convert them into the most fine, flexible, and active ones, as the *Doctor's* scheme supposes.

* Optics, Quer. 31. p. 376.

CHAP.

thesis with the impiety of making God the *Soul of the World*, as the Heathens of old did. But this matter is not now before me; our business at present is to consider the force of this objection so far only as it is physical. It is in fact no more than this——mechanical causes use to act in proportion to the surfaces; but the cause of Gravity acts in proportion to the quantity of solid matter; therefore that cause cannot be mechanical."

219. "Thus much is certain, that every mechanical cause, which is not subtile enough to penetrate the contexture of a solid body, will be stopt at the surface; and the action or force of such a cause will be proportionable to the surface. If there were in nature *no other* mechanical causes, but such as act upon the surface, and it could be fairly made out, this objection would be unanswerable. It ought to have been proved, that there really are no other; at least it should have been attempted: Yet as far as I can find, it hath not; and I think it never will be, for the two following reasons."

220. "*First*, Because there may be in some cases an impelling matter, which is too subtile for the observation of our bodily senses: And to conclude that there can be no material agency, where it does not discover itself to the organs of the body, is rather too hasty. If the Parts of Man's Body, were of the substance of Iron, and put together in the same manner, he would probably feel the cause of *magnetism*, as plainly

plainly as he now perceives the heat of the Sun's rays, or the blowing of the wind againſt his Face: But then it would be of ſmall uſe, to loſe the motion of the joints, and receive a polar direction in the Body, merely for the ſatiſfaction of feeling, that the cauſe of magnetiſm is material and mechanical; which perhaps may be diſcovered, to as much ſatisfaction, by a more advantageous method."

221. "My ſecond reaſon for believing that we are to expect no proof of this negative comes a little cloſer to the point; and it is this; that the oppoſite affirmative is evident from a great variety of experiments; there being in nature ſuch mechanical cauſes, as are able to penetrate the ſolid bulk of bodies, and whoſe actions extend to every ſingle particle of which they are compoſed. The rays of *light* can paſs as eaſily through the ſolid ſubſtance of glaſs, if not *more* ſo, than through the open air: And it is plain, their effect on bodies is not regulated by the exterior ſurfaces, becauſe an hollow bubble of glaſs hath the ſame exterior ſurface, whether it be empty, or filled with water; yet the light is well known to take a different courſe through it in theſe two caſes. If a leaf of gold be held up between the Eye and the Sun's rays, they are not ſtopt by the ſurface of it, as a blaſt of air would be, but paſs its ſubſtance with great eaſe, and appear as a beautiful green colour on the backſide of the leaf. The electrical fire, when put in motion will paſs off in a

ſtream through the denſeſt bodies, and can *penetrate the inmoſt ſubſtance of their ſolid matter:* The influence therefore of ſuch a material cauſe will neither be confined to the ſurfaces, nor be proportionable to them: And I am willing to think, that if Sir *Iſaac* had lived to ſee ſome wonderful effects of this fluid, diſcovered for the moſt part ſince his death, he would have enlarged his notions very much with regard to the natural power and extent of *mechaniſm.*"

222. "There is hardly a motion in nature, which this fluid, when applied by a diligent experimentaliſt, is not capable of producing: It will give a *rectilinear* motion in all directions; will produce the motions of *rotation* and *revolution,* as a *common fire* will alſo do: It will keep a body ſuſpended at a certain diſtance in air, without any viſible cauſe, and make it turn ſwiftly on its axis: It will accelerate vegetation, increaſe the motion of the blood in the arteries, raiſe water into tides; and in a word, will ſhew itſelf, as a *natural inſtrument,* to be little leſs than all-ſufficient."

223. "From theſe and many other experiments open to common obſervations it muſt appear to every unprejudiced Philoſopher, that nature is furniſhed with a mechanical cauſe whoſe activity is not confined to the ſurfaces of bodies, but extends to their conſtituent parts, that is, to their *quantity of ſolid matter.*"

224. "The ſagacity of Sir *Iſaac Newton* could not well overlook this; and he ſeems to

have apprehended ſuch a thing, having affirmed no more, than that mechanical cauſes *uſe* to act in proportion to the ſurfaces: But unleſs they *always* do ſo, by a neceſſary and invariable rule, the inference, that Gravity *cannot* be the effect of ſuch a cauſe, is of no force at all. And there is good encouragement to think, that Gravity not only *may* be the effect of a material cauſe, but that it really *is* ſo; and that this cauſe might poſſibly be pointed out, and proved by experiment. But I muſt remember, that I am not now accounting for the difficulties in natural Philoſophy, but only removing thoſe objections, which lie in the way to a *phyſical* ſolution of them."

225. Mr. *Jones* informs us, that there is a *phyſico-mathematical* argument of ſome weight, which ought to be conſider'd. "It hath been objected, he ſays, that *Gravity* cannot be owing to any *mechanical* cauſe from the manner in which ſuch cauſes are obſerved to produce their effect."

226. "Thus, for example, when a Ship is put in motion before the wind, the *velocity* of the wind, with *reſpect* to the ſhip, will be leſs when the ſhip has *acquired ſome motion*, than when it was at reſt, the accelerations in equal moments of time will be unequal. After the firſt impulſe, the acquired velocity of the body will be ſubducting more and more from the *relative velocity* of the fluid; on which account, the accelerations in equal times will be leſs and

leſs, till the reſiſtance the body meets with in its motion, becomes a balance to the force that moves it; at which point the accelerations wholly ceaſe, and the ſhip thenceforwards goes on with an equal pace."

227. "This, it muſt be confeſſed, is very different from the manner in which the cauſe of gravity produces its effect: For this Cauſe, whatever it may be, *acts inceſſantly or continually, and with the ſame force upon a Body that is already in motion, as upon a Body that is at reſt; which appears from hence, that it produces equal accelerations in falling Bodies in equal times*.*"

228. This property of Gravity is manifeſt from ſome abſtracted mathematical reaſoning, which *Galilæo* confirmed by experiment. If a Body ſhould continue to fall during the ſecond moment of time, with the velocity it had acquired at the end of the firſt moment; it ought to fall *twice* as far in the ſecond moment, as it did in the firſt. But it is obſerved to fall *thrice* as far; therefore it has derived from its cauſe in this ſecond moment, another third quantity of motion, equal to what it derived from it in the firſt. And this law it will continue to obſerve in all the ſucceeding moments, ſo far as human obſervation is able to follow it."

229. "According to the received principles, this argument, as here ſtated, bears very hard

* *Maclaurin*'s Phil. p. 241.

upon

upon the mechanism of Gravity. What I have to offer against it is this —— that the accelerations of a body, moved by wind or water, are continually decreasing *only upon this account* — because the velocity of the body, after the first impulse, approaches *sensibly nearer* to the velocity of the fluid. If the velocity of the fluid should be so great, that the velocity of the body shall bear no *sensible proportion* to it, the objection will vanish. And this observation, I humbly apprehend, is applicable to the cause of Gravity. For if that effect is owing to any *physical* cause, it will in all probability prove to be the same with that which produces such wonderful effects in Electricity: The *velocity* of which, is not to be measured in any trials we are able to make upon it; and for ought we know, may be as great as that of the *light* in its progress from the Sun and Planets: So that the velocity of a falling body, as far as experiments have gone, will bear no sensible proportion to it. Therefore the effect ought to be, such as it is found to be."

N, B. The Law observed by falling Bodies is, that the accelerations are as the increase of the times or moments taken up from the beginning of their fall, in an arithmetical progression of the most simple series, *viz.* 0, 1, 2, 3, 4, *&c.* whose excess and common difference is *one*, and for that reason their squares will be found to increase according to the odd, i. e. the *uneven* numbers 1, 3, 5, 7, *&c.*

o | 1

0	1	2	3	4	5	6	7	8	9	10
0	1	4	9	16	25	36	49	64	81	100
	1.	3.	5.	7.	9.	11.	13.	15.	17.	19.

That is, the *first* Series shew the *Number of Moments*; the *second* Series, (being the Squares of the *first*) shew the several accelerations or Spaces described every succeeding Moment; and the *last* Series, the Increase of each square.

230. That which serves to illustrate and confirm the truth of Mr. *Jones*' Opinion concerning the cause of the acceleration of falling Bodies, is an Experiment, the effects whereof most evidently point out such a *subtile elastic* Fluid, perpetually passing down to the Earth from the upper Regions, but with what velocity is uncertain; insensibly pervading the pores of gross Bodies, and *visibly* driving the magnetic Needle round and round the Compass at pleasure.

231. The method to effect this, and by that means to render such a descent of an elastic fluid sensible, is to bring the lower-end of any vertical iron Rod toward the North end of the Compass-needle, which will *repel* it so long as it pursues it; but if it be brought near the South end of the Needle, it will *seem to attract* it round. And on the other hand, the upper end of the Rod will repel the South end of the

the Needle and *ſeem to attract* the North end*, as is particularly deſcribed. Part I. Sect. 158. Is not the *cauſe* of this the magnetic Fluid in a different dreſs, i. e. the Pneuma, or Spirit of Æther, ſince iron and ſteel Rods only will ſerve the purpoſe? Whereas, the effects of the common experiments made at the electrical Apparatus are equal with reſpect to all Metals.

232. Hence it is evident that the magnetic virtue, or what is term'd *Pneuma, Spirit* or *Eſſence* of Æther, is more active and ſubtile than the Æther produced in the common experiments made at the electrical Apparatus. Hence alſo the effects of the vertical iron Bar, indicates or points out an elaſtic fluid conſtantly deſcending through it, and that the ſame homogeneous fluid

* This Experiment is mention'd by Mr. *Boyle*, who, after ſpeaking of the magnetiſm acquir'd by the Iron Bars of Windows or any other that had ſtood a conſiderable Time in a vertical Poſition, ſays; —— "I have found indeed that if a bar of "Iron which has not ſtood long in an erect poſture, "be but held perpendicular, the ſame Experiments "will ſucceed; but then this virtue, diſplay'd by "the extremes of the Iron, will be ſo tranſient, "that if the bar be but inverted, and held again "upright, that end, which juſt before was upper-"moſt, and drew the north point of the Needle, "will now, being lowermoſt, drive it away; which "will not happen to a Bar that has been for ſome "Years kept in the ſame poſition." *Boyle's* Philoſ. abridg'd by *Shaw*. Vol. I. p. 498.

fluid is as conſtantly paſſing through the Compaſs-needle, *viz.* from the South to the North end. The elaſtic particles iſſuing out of the lower end of the iron Rod, naturally repel the ſame homogeneous particles flowing from the north end of the needle, and for that reaſon the north end of the needle neceſſarily recedes from the lower end of the bar; but when brought to the South end, it has a quite contrary effect. In iron bars that have been a long time vertical, the effect is ſtill much greater; but of this more when I come to treat of magnetiſm.

233. Since then a ſubtile elaſtic Fluid ſo evidently appears to be conſtantly paſſing to the Earth from the upper Regions, is it not rational to ſuppoſe that the conſtant current of ſuch a ſubtile elaſtic fluid to the Earth, may be the principal if not the only mechanical cauſe of the gravitating tendency of bodies towards the Earth's center? May not this, if the motion be ſufficiently rapid, accelerate the motion of falling bodies in the manner Mr. *Jones* has been deſcribing? And tho' mechanical cauſes were obſerved to act on the ſurfaces only of bodies, yet this cannot be univerſal; for do not the effects of this experiment as well as thoſe in Electricity evidently point out a ſubtile elaſtic agent which penetrates to the inmoſt receſſes of compound bodies, and conſequently muſt preſs upon every the leaſt corpuſcle, or moſt minute atom of falling bodies? Theſe things conſider'd,

muſt

muſt not every ſuch body neceſſarily gravitate according to the *quantity* of matter contained in it?

234. Such intereſting conſiderations, 'tis preſumed, will meet with due attention; and the ſame kind of experiments be thought well worthy of cultivation by all true lovers of Science, particularly as nothing, before the diſcovery of ſuch a ſubtile elaſtic principle, was thought *capable of penetrating* and acting freely, beyond the ſurfaces of groſs bodies, which thoſe experiments effectually ſhew to be a miſtake.

235. That the magnetic virtue, the electric virtue, and the fire of lightning, are all of them one and the ſame identical principle under different forms, cannot be reaſonably doubted, ſince the effects produced by each are the ſame; magnetic polarity, for inſtance, is evidently generated in bars of iron and ſteel by means of the ſubtile elaſtic fluid conſtantly paſſing thro' them.

236. *Firſt.* Dr. *Franklin* has preſented us with a method to give ſuch a polarity to common needles as to cauſe them to traverſe when laid on water, and informs us that it was a frequent experiment at *Philadelphia* to give a polarity to needles by paſſing the electrical flaſh through them.

237. *Secondly.* From the effects of the above experiments it evidently appears not only that a ſubtile elaſtic medium is conſtantly deſcend-

ing to the Earth; but also that the same subtile agent by means of such descent, is the cause why iron and steel bars are magnetically impregnated, and as we also find by experience that it passeth more freely through them than through other metals: Is it not then reasonable to suppose that by such a constant current thro' the pores of those bars, it forms somewhat of apt roads or channels, since it is always found that the longer such iron vehicles have stood in a vertical position, the more effectually is that property impressed on them?

238. *Thirdly*. The same thing is effected from a flash of lightning as may be effected by a flash of electrical fire. By flashes of Lightning Captain Waddel's Compasses either lost the virtue of the Loadstone, or the poles of the Needles were reversed, the North point turning to the South. See Dr. *Franklin*'s Letters on Electricity, p. 90.

239. If then Sir *Isaac Newton*'s 1st Rule of Reasoning in Philosophy be just, which *admits of no more Causes of natural Things than such as are both true and sufficient to explain their Appearances*, we must conclude the Fire of Lightning, the electrical Fire, and the magnetical virtue or Effluvia, to be one and the same subtile elastic Fluid, acting in different Forms.

CHAP.

CHAP. XIV. PART III.

SECTION 240.

A Summary of Mr. Jones' *Essay.*

HAVING occasionally given my Readers, in the course of the preceding Pages, several pertinent and interesting Quotations from Mr. *Jones'* celebrated Essay, in order to excite them to feast their Intellects with the still higher Entertainment which they will be sure to find from their perusal of the *whole*; I shall now beg leave to subjoin *a compendious view* of that curious Tract executed by the same masterly hand, as a farther Specimen of the great Talents of that accomplished Writer, whose Work is too nervous in every line to bear the least abridgement, and can then only be read with all its advantages, when it is read in the form in which the ingenious Author himself has presented it to the World.

241. "It may be of use now, says he, to collect into one view the evidence that hath been offered; and to consider at the same time, what, and how much, we have a right to conclude from it."

242. "In the prosecution of this work upon the *Mechanism of Nature*, I have endeavoured

to disprove all that hath been advanced on the other side of the question; and to establish the affirmative, by an induction of so many positive proofs from nature and experiment as may serve to put it out of all dispute."

243. "First then, it is clear enough, that the operations of nature *may be* mechanical; notwithstanding all the objections, arguments, and demonstrations, which have been invented to support a contrary opinion. Some of these objections are no better than naked and unsupported assertions; which prove nothing, but that the Authors of them were persuaded of what they asserted. Other objections are drawn from the *difficulty*, which the learned have found, in assigning a mechanical cause for some particular effects; and these difficulties have been improved into absolute impossibilities: As if it were impossible for God to contrive, what it is not easy for Man to comprehend. *Cohesion* hath been a great difficulty: *Gravity* another difficulty: And if there were five hundred more, would it not be wrong to draw any positive conclusion, from what, by our own confession, we do not understand? The industry and experience of future times, taking all due advantage of some modern discoveries, may make some things clear and easy, which at present are accounted unfathomable. And Man, after all his labour in this life, must expect to find many difficulties, and have the mortification to be ignorant of many things. But how preposte-

rous would it be, to begin a ſyſtem with thoſe Articles, concerning which we have no certain knowledge! It would be like the practice of an Architect, who ſhould undertake to build a Church, and begin with the weather-cock."

244. " As to *Arguments*, the moſt important of all others, and that which moſt nearly affects the notion of an univerſal mechaniſm, is the proof of a *Vacuum:* Not only as the poſition itſelf doth neceſſarily exclude all ſecondary cauſes; but as it pretends alſo to be founded on facts."

245. " The Barometer ſinks when it is carried higher up into the atmoſphere; but the argument, commonly deduced from this experiment, proves ſo much, that it proves nothing. For at this rate, there ought to be a vacuum, where our ſenſes, with the help of ſome common experiments, aſſure us there can be no ſuch thing. Fire, which burns and flames beyond the height to which the twilight is extended, will neither burn nor flame in a vacuum."

246. " Sound alſo is tranſmitted from thence, if accounts atteſted in the beſt manner deſerve any credit, perhaps more audibly than it would be at an equal diſtance upon the Earth's ſurface. Theſe obſervations will not conſiſt with a vacuum: They will only lead us to ſuſpect, that the element of *Air* is but imperfectly underſtood."

247. " If we go higher up into the heavens, there again we meet with the *Phænomena* of

Comets; of the *Philosophy* of which Bodies, but little more appears to be known, than that they disprove the notion of a celestial vacuum ; for they burn, and flame, and send out vapours, just as they would do, if the *Air* were present to them. Sir *Isaac Newton* hath been beforehand with us in stating this argument; though in opposition to his own opinion, upon some other occasions."

248. "From the *resistance* of different mediums, a *demonstration* is supposed to have arisen for the proof of a vacuum, as absolutely necessary to an undecaying motion."

249. A Body, it hath been asserted, must *lose* its motion, by *communicating* it to the medium through which it passes : And this supposition is well known to be the foundation of that famous superstructure, which hath done so much honour to the geometrical talent of Sir *Isaac Newton*. It is upon *this account only*, that he will have the celestial spaces to be void of all *sensible matter*; and thence he takes occasion to introduce *attraction* and *projection* as the only possible causes of the planetary motions. Whereas in fact, a Body may preserve an equal pace through any medium, and its resistance shall be no argument to the contrary, if that medium is appointed to act as the immediate *cause* of the motion. Nor is this a bare speculation, depending on such principles as must be committed to the courtesy of the Reader; for the thing is reducible to practice."

250. "Air is a reſiſting medium; yet inſtead of *retarding* the motion of the *Lamp-machine* by its *reſiſtance*, it preſerves that motion by its impulſe. And if the motion is diſcontinued at laſt, this is not owing to any defect or irregularity in the *cauſe*, but to the imperfection of the *materials*. If the materials, which are acted upon, would but continue in the ſame ſtate, the motion would be unretarded, ſo long as Air and Fire, which are the cauſes of it, ſubſiſt in the world."

251. "In this experiment, the cauſes are not *artificial* and *violent*, as when a circular motion is given to a ſtone whirled about in a ſling, or to bullets carried about in a box by the revolutions of a *centrifugal-table** *&c.* but ſuch as are ſupplied by nature itſelf, in its regular method of acting; which both *begins*, and *continues* the motion †. What is done by nature in one caſe, may certainly be done in others. The Planets themſelves may be carried round in their Orbits by the ſame means."

252. "The Heavens may be filled throughout with an ætherial fluid; not infinitely rarefied, unreſiſting, and impotent; but denſe, and continuous in its parts: For if ſuch a fluid is contrived, by the great Author of nature, to govern and regulate the planetary motions; never let us fear, that it will obſtruct and re-

* A mechanical Experiment. † A true phyſical Experiment.

tard

tard the *motion which it gives.* From all this, we have ſufficient reaſon to conclude, that the operations of nature *may* be mechanical."

253. "Nor is it leſs evident that they really *are* ſo. In all thoſe experiments, where there can be no reaſonable doubt about the explanation, matter is found to act upon other matter, for the producing of the effect; and we are able to trace this in ſuch a variety of inſtances, that unleſs the world is governed by oppoſite and contradictory principles, the ſame Rule muſt obtain throughout the whole."

254. "The Body of Man, which is the higheſt piece of machinery in Nature, is made to *ſee*, and *hear*, and *ſpeak*, upon mechanical principles; and it dies without the conſtant impreſſion of a *material* force upon it, from the element of *Air*. By the preſſure of this Air, the Mercury is made to riſe in the tube of a Barometer: Hail, ſnow, and vapours, are formed in the atmoſpherical Regions, by the different temperatures of it: The Clouds are ſuſtained by it, and driven about to water the Earth: Plants grow and are nouriſhed by it: Without it, there could be neither Sound, Voice, nor Language: All Fires would be extinct: All Animals, whether Fowls, Beaſts, or Fiſhes, would periſh; and the whole World would languiſh and decay."

255. "For thoſe effects, where the cauſe is not ſo obvious, a more ſubtile *Æther* is provided; the reality of which hath been proved,

and

and many of its operations pointed out by experiment. It is capable of being transfused, as an element, from one parcel of matter to another. On some occasions, it will add a remarkable increase to the weight of Bodies. It will enter the pores, and fill the interstitial vacuities of all other substances; and it acts with a force, and a velocity, adequate to all the effects we can desire to ascribe to it. It gives an *elastic* force to *Air*, and occupies every space from which the Air is exhausted. In Electricity, it shews itself to be *light*, and will occasionally burn and consume Bodies as *Fire*. It is therefore both Light and Fire: Light, as it illuminates, and renders objects visible; Fire, as it burns and consumes what it acts upon. In the fire of lightning, it appears by inference, to consist of the same matter with the rays of the Sun; a consideration, which, in common with many others, renders it universal to the whole system of the Creation."

256. "These are the instruments, which God hath manifestly ordained, as secondary and subservient to his own Power, in the Oeconomy of the material world; and they are so universally extended, and incorporated with other things, as to be serviceable in the motion of all its particular parts. Some or other, and in many cases each of these, are present to all those effects which have fallen under the observation of Philosophers; and there are no other causes to be found; unless we ascribe unintel-

ligible and innate powers to inert matter, thereby making the effect to be the Cause of itself; or can suppose, against the dictates of reason and common sense, that God, who hath created these means, hath made it a rule to act without them. Of these both Art and Nature receive the benefit in common."

257. "What strange things are brought to pass by every ordinary Blacksmith, only by the application of fire and air from his forge and his bellows? If he turns these out of his shop, the strength of his hands will do him but little service; and the rest must be left to attractions and repulsions: But iron and brass do not understand the force of such Philosophy. What would the Chymist do, without his furnaces and his refrigeratories? Hence proceed all his separations, sublimations, condensations, fixations, digestions, chrystallizations, and such like. With the help of these natural causes, very few things are too hard for him; but without them, his whole Art would be at a stand."

258. "The Chemist sees this and confesses it: He cannot but observe the uses of fire and air within the sphere of his Laboratory; and is thence naturally led to acknowledge their uses in the greater operations of Nature. Hence it comes to pass, that there are few chemical Writings extant, which will not afford some light to a natural Philosopher; but above all others, the Writings of Dr. *Boerhaave* ought to be valued on this account."

259.

259. "What fruit then can be expected from the labours of any disquisitor, where he neglects these elements, and would banish them, to make way for such causes only as can operate in a vacuum? He must of course deface the chief beauty of nature; which is no where so conspicuous, as in the dependence that is established between effects and their causes; and must empty the world of its matter and mechanism, only to fill it with difficulties and mysteries. If he destroys the connection between the parts of matter, he must present us with such a picture of nature, as can resemble nothing but the bones of a skeleton, which cannot stir one step upon natural principles: Whereas the Work of God is worthy of its Author, and the frame of Nature is a perfect and well connected body, furnished with all its proper muscles and ligaments. The bones are united, moved, and lifted by the muscles: If an Anatomist, in describing the wonders of the human frame, should leave out these, he must suppose the bones to move themselves; after which, he might go on to argue *against* the muscles, as things useless and unnecessary, mere obstacles to the free and easy motion of the bones within their sockets; and then he would philosophize just as they do, who forget that fluid matter of the Heavens, by which all other things are moved and connected together, and place occult powers in the solid matter of the celestial Orbs."

CHAP. XV. PART III.

SECTION 260.

A brief Account of Magnetiſm.

HAVING, I hope, irrefragably proved that an active Matter exiſts in Nature, as well as a paſſive, and that the former is *real and true Fire*; I ſhall now proceed to enquire how far that active Principle may be reaſonably ſuppoſed to be concerned in producing the various Phænomena of Magnetiſm.

261. Now Magnets are of two kinds, *natural* and *artificial*.——By natural, I mean, not only the Load-ſtone, but all iron Bars that by long ſtanding in a vertical poſition have acquired a magnetiſm, that is, Properties ſimilar with thoſe of Loadſtones: Theſe I alſo call natural magnets, ſince they naturally acquire the magnetic virtues; and this is ſuch an important hint, that were it duly attended to, it might conduct us to a ſatisfactory explication of that difficult and myſterious branch of Philoſophy.——The moſt remarkable of theſe bars are thoſe on Towers, and in the Windows of the moſt ancient Buildings, ſuch as Monaſteries, Churches, *&c.* ſome of which exhibit a Magnetiſm more powerful than the Loadſtone itſelf,

264.

262. Mr. *Boyle* obſerves "that the iron bars "of Windows by having ſtood very long in an "erect poſture grow magnetical, inſomuch "that if the north end of a poiſed Needle be "applied to the bottom of it, that end will "drive the Needle away and attract the ſouth-"ern; and if the Needle be raiſed to the up-"per part of the bar, the north end will be "attracted, and the ſouth end repelled." The truth of this I have frequently proved at the bars of different Windows in the Cloyſters of the Cathedral of Worceſter.

263. M. *Lewenhoeck* gives us an account of an iron croſs, which was ſuppoſed to have ſtood on the ſteeple of a Church at Delft about 200 years, ſome pieces of which he procured that had a ſtronger magnetic virtue than two Load-ſtones which he then had in his cuſtody, and ſo hard that no file would touch them. Philoſ. Tranſ. No. 371. p. 72.

But the aforeſaid property in ſuch ancient vertical bars of iron is ſo well known as not to need any farther proof.

264. As to *artificial Magnets*, there are various methods of making them: What ſeems to have afforded the greateſt light into their formation was the Phænomena exhibited by thoſe vertical iron bars aforementioned*. This was the ready road to conduct us to the knowledge, that a ſubtile elaſtic fluid was inceſſantly paſſing through every *common* vertical rod or

* Tongs, Pokers, &c.

bar

bar of iron, and, in a word, that ſuch a ſubtile Æther was perpetually and ſwiftly paſſing from the upper Regions to the Earth and all rarefied parts, but the moſt eaſily and freely through thoſe iron and ſteel vehicles.

265. From hence it appears that what we term Magnetiſm is communicated to Magnets by means of a ſubtile Matter conſtantly paſſing through them; and what ſeems to put it paſt diſpute, is an experiment of the ingenious Dr. *Franklin*. See Part III. Sect. 236. 237. 238.

266. On trying the effects of common iron bars when brought to the Compaſs-needle, I found them poſſeſſed of the ſame Property with the other, though in a much leſs degree. See *Note*, p. 407.

267. Why iron or ſteel bars ſhould render that Phænomenon more conſpicuous than any other kind of metal, is a ſecret not yet fathomed; but the effects of thoſe experiments alone, ſufficiently evince that a more ſubtile active agent exiſts than the common air, or even than the ſubtile fluid latent in the pores of groſs bodies, ſince we find *that* capable of pervading that very Æther itſelf in their interſtitial vacuities. Philoſophers will therefore be much leſs embarraſſed than heretofore, for a phyſical Principle capable of penetrating the inmoſt receſſes of the denſeſt bodies, to enable them to gravitate or deſcend: And is not this the Agent that cauſeth matter to cohere?

268. From the foregoing Reaſoning it plainly

ly appears, that the comparing of Magnets to the Earth, and laying it down as a firſt and fundamental Principle that every Magnet like *that* was poſſeſſed of two Poles, an Equator, and an Axis, was very far from the ſureſt way to inveſtigate a true Theory of Magnetiſm, ſince by Poles in the Earth we mean fixed points; whereas when we examine what are termed Poles in a Magnet, we find them of the moſt fugitive and mutable nature, and may be reverſed at pleaſure, and this in many circumſtances almoſt inſtantly, and not only ſo, but the Magnets themſelves may be multiplied and divided, and yet each one will retain all the properties of the firſt.

269. Theſe Qualities, ſo remarkably obſervable in every ſection of a Magnet, reminds me of the ſimilar properties we find in that prodigy of Nature, that Aquatic-vegetative-animal called a *Polype*, of which we are credibly informed, that if the Tail-end of the Body be cut off, the reſt of that ſurpriſing Creature will almoſt immediately after, purſue its prey with vigour; and not only ſo, but another Tail-end of the ſame kind will vegitate to ſupply the place of the firſt, and that the ſame vegetation will follow, even though the Head were cut off; and what is ſtill more wonderful, if it be divided in the midſt, it will not even then be deſtroyed, but ſo far from it, that it will by that means be multiplied into two of the ſame kind, each of them perfect; for not only out of the foremoſt

half

half a Tail-end will germinate, but out of the hinder-part sprouts a Head also*.——Whether this account of the Polype be true or fabulous is not material, but something analogous to this would appear in Magnets, if we suppose an *attracting* and a *repelling* Pole in every one; for if either end of the Magnet be cut off, though beyond the part where the Pole is supposed to be situated; yet a Pole of the same kind is instantly generated and acts as vigorously as the first: And if the Magnet, like the Polype, be divided in the midst, it is multiplied into two; for that which was the North end of the magnetical bar becomes a compleat Magnet, a South pole being immediately generated at the new South end of it; and in like manner, the South half of the original bar becomes a compleat Magnet also, for a new North pole is immediately formed at the *North* end of it.

270. Since then such a variety of Experiments most evidently point out so material a mistake as that of supposing two Poles in every Magnet, the one to attract and the other to repel, which proves to be only the ingress of the magnetical virtue at the South part of the Magnets and the South ends of Compass-Needles, and its egress at the North; as also an

* That such a species of Creatures exist is certain, I having formerly seen several of them which were kept in a glass Jarr of Water till a severe Winter kill'd them.

ingress

ingreſs at the upper end of a bar of iron, and an egreſs at the bottom. So long as we were ignorant of this, innumerable ambiguities and unſurmountable difficulties muſt be inevitably diffuſed throughout that branch of phyſical Science, Magnetiſm.

271. But unleſs we attend moſt ſtrictly to that exceſſive, that exquiſite rarity and elaſticity which Sir *Iſaac* diſcover'd in Æther and is now verified in the electrical Fluid, we ſhall be in imminent danger of loſing the guiding Clue, and then almoſt all that is valuable will be loſt along with it; for upon theſe two eſſential Properties the whole Myſtery is diſcover'd to depend.—— I ſhall next endeavour to render my meaning more plain with reſpect to ſuch a guiding Clue.

272. It hath been already obſerved that the exiſtence of a *Pneuma*, or ſuch a *Spirit of Æther* as aforementioned is obvious, not only in electrical Experiments, but in other Phænomena of Nature. The particular Experiment to which I ſhall firſt refer is that which we find mentioned by the ingenious and honourable Mr. *Boyle*, which Experiment, though in ſeeming miniature, may notwithſtanding be accounted a leading one to farther diſcoveries ſince it is purely phyſical.

273. " To ſhew, ſays he, that the particular and uſual manner of exciting electrical Bodies by rubbing them is not always neceſſary, I took a large piece of good Amber, and having

in a Summer-morning, whilst the Air was yet cool, and finding that it would not without being excited, attract a light body, I removed it into the Sun-beams, till they had made it moderately hot; and then found, it had acquired an attractive virtue; and that not only in one particular place, as when it is excited by rubbing, but in several distant places at once*"

274. In that Experiment the Equilibrium was first destroyed by means of the Sun's beams striking on the electrical fluid fixed in the pores at the surface of the amber: For although by being firmly fixed in the amber, it is prevented from moving out of it; yet, being exceeding susceptible, and at the same time so impatient, as it were, of the least friction or attrition, that notwithstanding, I say, it cannot move out, yet, from the effects of experiments, its influence or emanation appears to extend to some distance from the surface, and by means of the elastic particles which form those limits, the surrounding Air is buoyed up and borne away from the amber, though not so as to terminate in a mathematical superficies, but grows gradually from the electrical body more gross till at the farthest part of those ætherial limits, it becomes equally gross with the common air surrounding those rare limits, which limits are no sooner formed than the *Pneuma, Essence, or Spirit* rushes in to restore the destroyed equilibrium, and drives

* Mr. *Boyle*'s Works Vol. I. p. 400. *Shaw*'s Abridgement.

light

light bodies into that vacuum or moſt rarefied part.

275. Since then a more ſubtile Agent than even the very electrical ſubtile Medium itſelf, is ſo clearly diſcover'd to paſs through vertical bars of iron, horizontal bars*, and even thro' ſo denſe a body as Glaſs, and that as freely as if nothing were in the way, like the magnetic virtue; conſequently by Sir *Iſaac*'s 1ſt and 2d Rules of Reaſoning, the ſubtile Agent concerned in Magnetiſm, and the forementioned *Pneuma*, muſt be one and the ſame identical Principle in different forms: And ſince eſcaping to the moſt rarefied parts is a moſt predominant propenſity of that ſubtile ſpirit, is it not from hence reaſonable to conclude that when the ſame *Pneuma* is arrived at the Earth from the upper regions, and the ſame propenſity of eſcaping to the moſt rare parts ſtill prevailing, that moſt rare part appears from the effects to be in, or toward the North, ſince we find the ſame ſubtile Agent readily paſſing through every Compaſs-needle from ſouthward to northward?

276. What then can be the particular part which is ſo very much rarefied, as to cauſe that prevailing tendency of this active Agent towards *that* more than to another? Is it not the magnetic pole or point, towards which the magnetic needle is always directed? Is it not reaſonable I ſay to ſuppoſe theſe things, ſince

* Such as the Mariners Compaſs-needle.

they are each of them agreeable to experiment and long obſervation, and conſequently not diſagreeable either with Reaſon, mechanical Agency, or Sir *Iſaac*'s Rules. But more of this when I come to treat of the *Variation* of the Mariner's Needle.

277. When all the moſt material parts of this Chapter are laid together and diligently compared, may we not ſafely infer that enough hath been ſhewn to convince us, that there can in fact be no ſuch things as thoſe points called Poles and Equators, either in iron bars magnetically impregnated, or in natural Magnets? For if that were allowed, we muſt be obliged to allow the ſame Poles and an Equator to every common bar of iron, ſince we find the ſame property in every bar ſo long as it is held in a vertical poſition, only in a leſs degree.

278. If it be aſked, what I ſhould gain that could prove uſeful either as to Magnetiſm in general, or in explaining any one ſingle difficulty relating to that abſtruſe ſubject, provided I could get fairly rid of ſuch Poles in Magnets? I anſwer as before, when reaſoning on the difficulties attending the ambiguous ſubject, Fire;

279. That every ſingle Error is generally productive of many others, and eſpecially if ſuch Errors are concerned in Fundamentals or Firſt Principles; for thereby the plaineſt ſubject is frequently render'd the moſt difficult: This is ſo well known as to need no ſort of proof. The ſureſt method therefore muſt be to endeavour

to get rid of every Error we meet with; for the more of thoſe obſtacles are removed, the more clear and open will be the way to truth.

CHAP. XVI. PART III.

SECTION 280.

Coheſion *conſider'd as to its phyſical Cauſe.*

ALTHO' I may poſſibly appear heterodox to ſome in the Articles of my philoſophical Creed, which I exhibit to the World in the preſent Publication; yet I perſuade myſelf the Authority I receive from the concurrence of many eminent Authors in the ſame Sentiments will ſo far apologize for me, as to procure me a cool and impartial Hearing.—— Amongſt the Advocates for my Opinions, Mr. *Jones*, ſo often before quoted, is far from being unworthy of our attention. On the Topic of *Coheſion*, he makes the following judicious Remarks.

281. "Inſtead, ſays he, of ſetting out here with recounting all the minute Phænomena of capillary tubes, ſponges, drops of quick-ſilver, &c. &c. which have all been enliſted as ſo

many undeniable proofs of an attraction of cohesion; though Sir *Isaac Newton* himself (more modest with all his knowledge, than some who have retailed his doctrines to us) proposes none of these with any thing more than a suspicion, or a conjecture concerning them; and some of them, as I could easily shew, have not been fairly reported or sufficiently inspected; I desire it may be considered——all the evidence of this sort is negative; and owes its whole worth to an arbitrary supposition, that the air is the *only* mechanical agent in nature; and that merely through the want of another, we must have recourse to immaterial qualities, exerted by the particles of the bodies themselves; there being *nothing else* *, to which these effects can be ascribed."

282. "To all this, I oppose the following positive matter of fact, worth an hundred little critical experiments, concerning which much may be said on both sides, while very little is understood on either. It is this——Nature is provided with the element of fire, a material agent of sufficient force and subtilty to overcome and undo the strongest effects vulgarly ascribed to cohesion. And as the design of our infinitely wise and bountiful Creator in appointing a material agency, was to build up rather than to destroy, to promote and preserve an

* See Mr. *Rowning*'s account of the capillary tube in the Preface to his System of Philosophy.

orderly

orderly diſpoſition in bodies, at leaſt as much or more than to cauſe their diſſolution; it is evident to reaſon, the ſame agent, acting with ſome difference of condition and circumſtances, muſt be ſufficient to do both. The Air when ſtirred into a tempeſt will tear an Oak, up by the roots; but was this the ſole end of its creation? Does not the ſame air aſſiſt the oak and all other trees in their growth? and does it not nouriſh and preſerve many more than it deſtroys?"

283. "Fire, another element, hath in like manner its different offices; and we may hope to gain ſome light into its more ſecret operations, if we argue by analogy from one of theſe to the other. That Fire is the great catholic diſſolvent of nature, the Chymiſts have all been ready enough to confeſs; that it can unite as well as ſeparate, ought not to be doubted; tho' it is what few will believe, unleſs they are poſſeſſed of patience and perſeverance enough to go through a cloſe enquiry. However, this matter is not ſo very difficult as they may apprehend."

284. "Let us conſider this agent a while in the firſt and beſt known of its capacities, I mean as a diſſolvent. The particles of mercury, from the ſphericity of its drops, ſhould ſeem to be endued with a ſtrong attraction; yet theſe particles will ceaſe to have any coheſion, and be ſeparated into fumes by a degree of heat but little exceeding that of boiling water. The

particles

particles of water are alſo ſaid to be endued with the like virtue: Yet the agency of fire will very ſoon relax their coheſion, as appears by a ſenſible diminution of their ſpecific gravity. The ſame fire acting with a ſtill greater degree of force, will at length totally diſſolve their union, and raiſe them aloft in ſteam or vapour. The ordinary heat of the Sun has a like effect on the Ocean. All other ſubſtances, as well ſolid as fluid, are ſubject to a ſeparation of their parts by entrance of fire: The hardeſt of metals, how cloſely ſoever their parts may be connected, are eaſily diſſolved and render'd fluid by the heat of a furnace."

285. "*Conlabefactatus rigor auri ſolvitur æſtu.* If Nature then is provided by its Author with an element of ſuch power and activity, as enables it to *overcome* the ſtrongeſt coheſions; it cannot be deſtitute of an agent powerful enough to *cauſe* them: If it can do the greater, it muſt certainly be able to do the leſs. And without much diſputing, do we not find it to be thus in fact? For the Æther, acting below a certain degree, will conſolidate the particles of water into ice: If it acts above that degree, it keeps the water fluid: If to an higher degree, it renders it more fluid: If to an higher ſtill, a total ſeparation of the parts will enſue. But if theſe parts mount up into the head of an alembic, where the action of the fire is different, they are united again into a well connected body. Theſe effects being anſwerable in

every inſtance to the activity and condition of a *material* agent, what neceſſity is there for calling in the aſſiſtance of an unmechanical *attraction?* The work *may* certainly be done without it*; and I am verily perſuaded, ſuch a principle would never have been ſeriouſly defended, if the agency of fire had been ſearched into as it deſerves. If I can ſee the effects vary, as oft as there is any change in the element of fire, I am compelled, by all the rules of Reaſon and Philoſophy, to underſtand this element as the immediate *cauſe* of theſe effects, and muſt receive it as ſuch, till it is demonſtrated to be inadequate; the contrary to which hath been demonſtrated already, and might be farther confirmed by ſome other experiments, which I might here introduce, if there were any occaſion for them."

286. "The Coheſion of bodies by the action of this fluid, may be illuſtrated and confirmed in a familiar way by ſome parallel effects, in the explication of which we are all agreed."

287. One of the experiments Mr. *Jones* refers to, is what is known by the name of the Magdeburg experiment; but as Mr. *Haukeſbee* has been more circumſtantial than Mr. *Jones* in relating that experiment, and alſo improved it, by varying it, I ſhall briefly give *his* account of it.

* Entia non ſunt multiplicanda abſque neceſſitate.

288. He took two braſs Hemiſpheres of three inches and an half in diameter, well fitted to each other, and had prepared ſuch an apparatus, that inſtead of exhauſting the air out of them, he crouded an atmoſphere of air extraordinary on their external ſurfaces, which he could eaſily diſcover by means of a mercurial gage prepared for that purpoſe, after which it required full 140 pounds to ſeparate them.

289. He proved farther, that if the experiment was varied into the form of the Magdeburg Experiment, i. e. by exhauſting the air out of them, they ſtill required the ſame weight to ſeparate them.

290. What proved ſtill more plainly that this Coheſion was not the effect of ſuction or any thing bordering on Attraction, but merely the preſſure and ſpring of the external Air, was the next variation of the experiment; when he not only exhauſted the Air, as in the Magdeburg Experiment, but having exhauſted the Hemiſpheres, he put them into his compreſſing Engine, and injected an Atmoſphere extraordinary on them as in the firſt experiment; at which time, 280 pounds was not ſufficient to part them; viz. double the weight which was neceſſary to part them before.—— And now I ſhall return to my Author Mr. *Jones* again.

291. He proceeds thus, p. 150. "If this reaſoning is juſt, the tranſition from the ſurfaces of the braſs hemiſpheres, to the coheſion of

the brafs itfelf, will not be difficult. For let this brafs be thrown into a furnace, it foon grows red; and as the heat increafes, it becomes in a manner tranfparent: The matter of the fire penetrates into the body of the metal; and when the medium within is nearly in the fame condition with the medium without, the brafs runs, and there is an end of its cohefion. An effect which is thus made to ceafe in a mechanical way, may be produced in the fame way; and if the entrance of the fire (as we argued above) diffolves and feparates the parts of the metal; the exterior preffure of the fame element, though in a different condition, was the true caufe of their cohefion."

292. "Deny the exiftence and preffure of the Air, and you muft have recourfe to attraction, or fuction, or an incorporeal agency, to account for the adhering of the hemifpheres: Allow but the exiftence and preffure of elementary fire, (the reality of which is manifeft to as many of the bodily fenfes as the reality of the Air,) and you need not have recourfe to any of thefe things to account for the cohefion of the brafs."

293. "Between thefe two effects there will be a nearer and more apparent refemblance, if the hemifpheres, inftead of being evacuated by the machinery of a pump, are heated moderately at a fire. The more fubtile fluid, rufhing into the concavity, expands and takes the place of fome of the groffer air, or *rarefies* it, as we

commonly ſpeak. In this ſtate let them be applied, with a luting of any kind to the joint, and dipt in cold water; they will adhere as effectually as if part of the Air had been withdrawn by exſuction. In like manner, when the fire diſſolves a maſs of metal, an extremely fine and ſubtile fluid paſſes freely through the body of it: But as it cools, this medium within, having no freſh ſupply, evaporates in part; and the remainder, growing continually weaker, yields to the ſuperficial preſſure of the ſame element, in a colder and leſs rarefied ſtate; from whence the whole effect muſt follow in a natural way; and the agent which drives the parts together, being univerſally preſent, will keep them together, till it is again counteracted as before. If any experimentaliſt ſhall hereafter be able to exhibit one ſingle inſtance of a cohering body, where he can prove the internal and external preſſures to be *equal* in all reſpects, we may then grant him his attraction; we may confeſs, ſuch an effect is not brought to paſs in a *phyſical* way; and that we underſtand no more of the cauſe of *Coheſion*, than he has expreſſed under that *word*; which is juſt nothing at all."

294. The following is another inſtance of a remarkable Coheſion performed by means of the preſſure of the common Air, which may ſerve as an illuſtration of the former.

295. "Let a ſtop-cock be faſten'd to the neck of a bladder, that it may be ſcrew'd upon the

the work of an Air-pump: Exhauſt the Air from it, and having turned the ſtop-cock, to prevent the Air from re-entring, take it off the machine. The bladder is now transformed into two flat ſkins, or rather ſimilar to two hemiſpheres ſo cloſely applied together, that the ſtrongeſt Man cannot raiſe one of them half an inch from the other; for, ſuppoſing the bladder to form the area of a circle ſix inches in diameter, each ſide is preſſed down upon its fellow, with a force equal to 396 pounds."

296. May we not from the effects of thoſe Experiments ſafely conclude, that we have made a diſcovery of no ſmall importance, and obtained a *ſight* of the cauſe from whence Coheſion proceeds, *viz.* from an external preſſure? We ſeem to have been hitherto greatly miſtaken concerning that Phænomenon; believing that an immechanical attraction was the cauſe why Bodies cohere, which we now have much greater reaſon to believe is effected by a different and contrary operation of Nature.

297. " There are, proceeds Mr. *Jones*, another ſort of reaſoners amongſt us, who ſeem to glory in their ignorance; and have precipitately defied all the Philoſophers upon Earth to account for coheſion, otherwiſe than by the Power of the Deity immediately intereſted. After the extravagant lengths theſe Gentlemen have gone, for the ſake of gaining ſome credit to I know not what metaphyſical *reveries*, they muſt be endued with a degree of candour and

ingenu-

ingenuity rarely to be met with, if they will attend to any thing of this kind. But I muſt beg leave to remind them, that if they will account for Coheſion by immaterial impulſes and miracles, they ſhould account for the adhering of the two exhauſted hemiſpheres after the ſame manner, and deny that the Air is employed as an inſtrument in this buſineſs. For I humbly think, it is conſiſtent neither with the Wiſdom nor the Power of God, that he ſhould ordain an inanimate ſubſtance to produce ſome effects, and produce other ſimilar effects by the immediate influence of his own divine Eſſence, becauſe they are conceived to be beyond the reach of any inſtrument even of *his* contriving. Such a concluſion as this, no pious Man, who is really concerned for the Honour of God, can eaſily digeſt; and Mr. *Boyle*, I am perſuaded, would never have admitted it. Nature is extremely ſimple in its agency, though infinitely various in its productions; It is not made to act by corporeal impulſes for the production of ſome effects, and by attractions and ſpiritual influences for the production of others. Of this ſimplicity in nature, if we can truſt to their own declarations, Philoſophers of all ages have been perſuaded; and it is no fault of mine, if ſome of them have unhappily departed from their own Rules." See Mr. *Jones* on the firſt Principles of natural Philoſ. p. 155.

298. To prove that the *Pneuma, Spirit*, or *Eſſence of Æther*, amongſt many other effects

which

which it produces, cauſeth matter to cohere, I ſhall firſt conſider the effects of two particular Experiments in Dr. *Deſagulier's* Courſe of Philoſophical Lectures, Vol. I. p. 183.

299. "I have, ſays he, applied together the flat ſurfaces of two ſmall cryſtal buttons, without wetting or oiling, which have cohered ſo ſtrongly as to hold 19 ounces Troy before they were ſeparated, when their contact was but a Circle of one twelfth of an inch in diameter; in which caſe the preſſure of Air could not be greater than the weight of an ounce; becauſe a column of Air, whoſe circular Baſe is one twelfth of an inch in diameter weighs no more."

300. "In Metals the ſame is evident, but more eſpecially in Lead; for two balls of Lead of about one or two Pound Weight each, if pared clean with a Knife and applied cloſe together, ſo as to touch in a Surface of about one tenth of an inch in diameter, will ſtick together ſo as not to be ſeparated by a leſs weight than of 40 or 50 pounds, though the preſſure of the Air in that caſe could not amount to one fourth of a pound." See Philoſ. Tranſ. No. 389.

N. B. When the leaden balls are cloſely preſſed together, it is neceſſary at the ſame time to give them a little twiſt. But my preſent buſineſs is not ſo much to ſhew that there are ſurpriſing Coheſions in nature, as to endeavour to aſſign the cauſe of them.——And this attempt will be not a little facilitated by conſidering the force of that inviſible *Pneuma*, or

Spirit

Spirit of Æther, which I have ſo often mentioned in the courſe of this Work, the effects of which are moſt obvious in Magnets, particularly in thoſe term'd artificial. And indeed there is ſuch a ſtriking ſimilarity or rather ſameneſs between Magnetiſm and Coheſion, that I have anticipated many of my Remarks on the latter ſubject by my obſervations on the former in the preceding Chapter.

301. Since the Rev. and very ingenious Mr. *Knight*'s diſcovery of a method of improving Magnetiſm, and of rendering it intelligible, by ſhewing not only the above mentioned Phænomenon exhibited by vertical iron bars, but alſo that the Magnetiſm acquired by them is ſtill capable of being much increaſed by tranſferring it to other bars, a *Clue* ſeems to be given us to direct our ſteps in purſuing the true Principles of Magnetiſm and Coheſion.

302. Nor are we leſs indebted to the accurate labours of the judicious Mr. *Canton* on this ſubject. It was not long ſince thought almoſt a prodigy to ſee one iron bar ſo impregnated with the magnetical virtue as to raiſe another of the ſame ſize when laid upon it; but that *Artiſt* applied one upon another, and they adhered ſo cloſely to each other that I could not ſeparate them, but with ſome difficulty, (the force I employed being ſufficient to have raiſed ſeveral pounds weight) particularly when I lifted my hand fairly upright; they were indeed parted with much more eaſe,

if

if I drew off the uppermoſt a little obliquely.

303. Is not this ſomething more than a mere glimpſe of Coheſion, and performed by the force of the forementioned Pneuma or Spirit of Æther ſo obviouſly paſſing through thoſe metallic vehicles?

304. But the moſt promiſing way to obtain a true idea of the manner by which Coheſion is effected, muſt be, previouſly to enquire into the moſt effectual means by which it may be deſtroyed. To effect this it ſeems neceſſary firſt to premiſe what we find aſſerted by Sir *Iſaac Newton*, in the concluding paragraph of his Principia, and confirm'd by a variety of the foregoing Experiments, particularly thoſe contained in the 3d Chapter of my firſt Part, *viz.* that of a ſubtile Medium exiſting in the pores of all groſs bodies, which ſubtile Medium when collected from their pores by the action of the electrical Apparatus, proves to be real and true Fire in the ſtricteſt ſenſe of the word.

305. When therefore metals are to be melted in the common way, it is not neceſſary to introduce any more fire into the pores of the metal to cauſe the fuſion. All that ſeems requiſite to deſtroy the Coheſion is only to communicate a ſufficient degree of heat to the component parts of that Fire already in their pores: Accordingly we find, that as ſoon as ſuch a heat is communicated to it, the expanſion of the particles of the fire contained in the pores becomes ſo violent, that the parts of the metal are

ſeparated, i. e. a fuſion enſues. But no ſooner is the violence of that heat a little abated, and by that means the expanſion of the particles of the internal fire leſſen'd, than the former coheſion of the groſs particles begins to take place again, and as the heat more and more decreaſes, that expanſion being thereby more and more contracted, the Coheſion becomes again more and more compleat: Or in other words:

306. The *Pneuma*, *Eſſence*, *Spirit*, or elaſtic preſſing Agent, which we find by experiment to be conſtantly deſcending from the upper Regions to the Earth in general and to all rarefied parts in particular, is the real cauſe why bodies deſcend with ſuch force, and why the parts of the metal cohered before and after the fuſion; which violent preſſing force of that agent is yet overcome by the more violent counteracting force of the expanded fire in the pores of the metal when ſo intenſely heated, that is, the violent intumeſcence or expanſion of the heated fire in the pores of the metal overcomes the elaſtic preſſure even of that very Pneuma, which before cauſed the parts to cohere, and by that means bears it away from the metal; this ſeems clear, ſince a fuſion immediately enſues, and continues ſo long as the ſame heat continues; but as before obſerved, when the heat, and conſequently the expanſion of the internal fire leſſens, the Coheſion again commences, and increaſes in the ſame proportion.

307. To conclude: Coheſion is performed

not

not only by the preſſure of the Atmoſphere, which acts only upon the *exterior* ſurfaces of Bodies, but more extenſively by the penetrating efficacy of the *Pneuma*, or *Spirit of Æther*, which reaches the *internal* Receſſes of all material ſubſtances, and connects and conſolidates all their Parts together.

308. I ſhall now conclude theſe Eſſays with the Words of that reſpectable Author, in whoſe correct Diction I have very frequently, in the preceding Pages, taken the Liberty of delivering my own Sentiments.

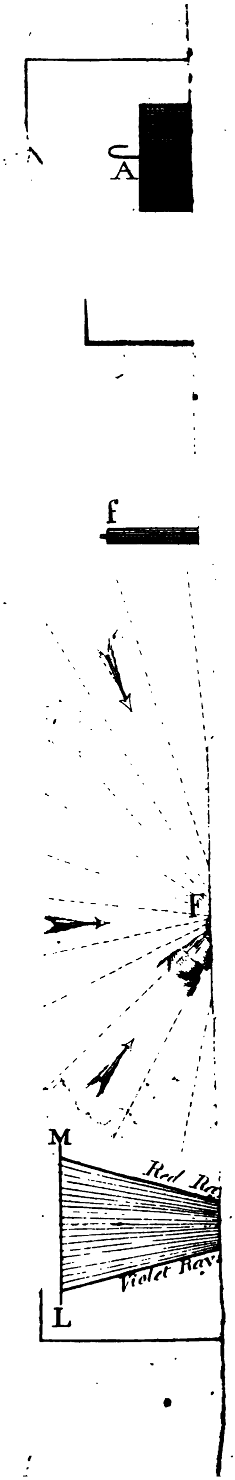
309. " To avoid falling into groſs Errors I have been careful to feign no arbitrary and abſtracted Idea of Nature; but have examined it wholly as a matter of fact, and have hitherto argued from obſervation only, in order to make ſuch a ſketch of its Outlines, as ſhall be like the original. And a ſtrong likeneſs hath often been hit by a very indifferent Painter; while ſome finiſhed pieces, which have ſhewn a maſterly hand, might as well have paſſed for the figures of ſome fictitious characters in a romance, as for the Perſons who ſat for them."

310. " With regard to my own reputation as a Writer, I am perfectly eaſy: For it was neither my deſign, nor my deſire, to exhibit a pattern of eloquence; but to add ſome little matter to the common ſtock of uſeful knowledge. It is in this light only, that I could wiſh to have my labours accepted. As to the Author himſelf, the learned, I hope, will find no reaſon

to

to look upon him as one who would dictate to those, who are better able to instruct him; or to impose a belief of any thing, which is not supported by plain argument, and undeniable evidence. If they do him justice, they will regard him only as a fellow-enquirer after that truth, which they also are desirous to find; and will attend to him, as to one, who takes great delight in the Works of God, and but little in any work of his own."

The End of the THIRD and LAST PART.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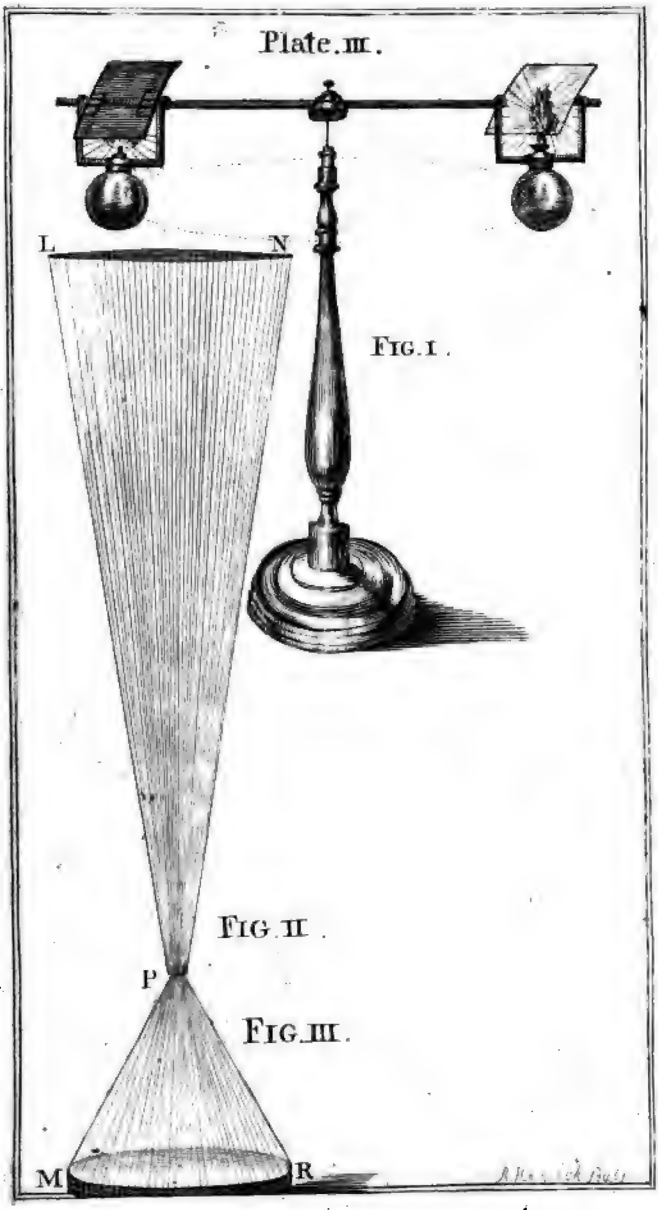
Plate. III.
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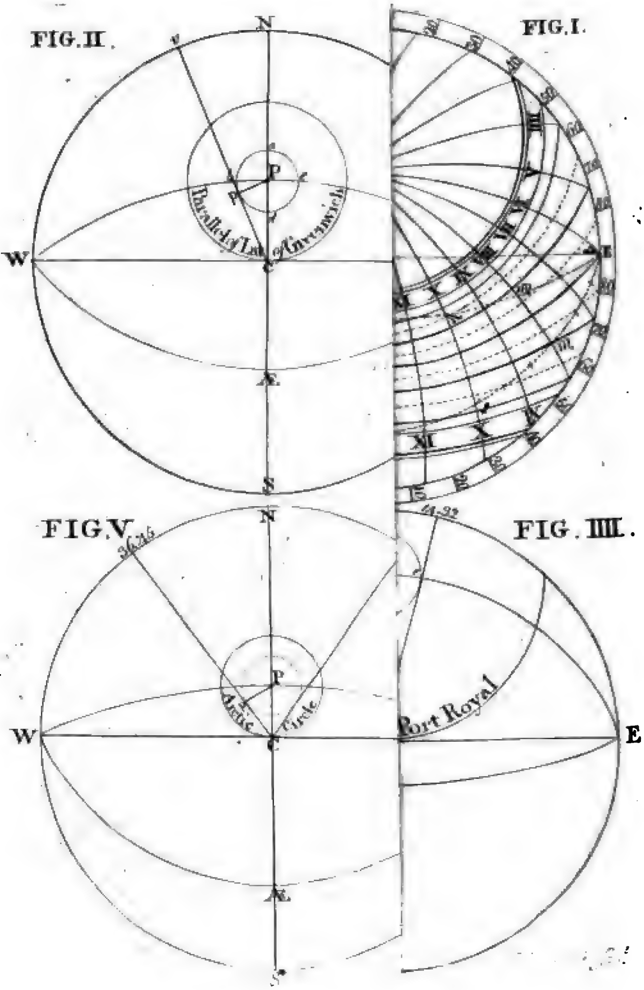
FIG.II.
FIG.I.
FIG.V.
FIG.IIII.
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Parallel of Lat. of Greenwich
Artic Circle
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AN

APPENDIX,

TO

Philosophical Essays,

In Three Parts:

CONTAINING

A Brief Theory of the NORTH

Magnetic-Pole,

And of the MARINER's

Compass-Needle;

In order to deduce *and* ascertain *the*

LONGITUDE,

From natural and permanent Principles.

By R. LOVETT.
Of the Cathedral Church of *Worcester*.

WORCESTER: Printed by R. Lewis, for the Author; by whom they are Sold: ——— Sold also by Mr. Sandby in *Fleet-Street*; J. Johnson, and Co. Booksellers, in *Pater-noster Row*, London; and by Mr. Fletcher, Bookseller, in Oxford, *&c. &c.*

A Brief Theory of the

North Magnetic-Pole;

And of the

Mariner's Compaſs-Needle.

IT may perhaps be thought ſomewhat abſurd, or at leaſt out of time, to publiſh *now* an Eſſay for the finding of the Longitude at Sea, after the truly ingenious Mr. *Harriſon* hath already diſcover'd it, and to ſuch a degree of accuracy and exactneſs, that, on the ſtricteſt ſcrutiny of the moſt ſevere Examiners, he hath been allowed and adjudged to be juſtly entitled to, and hath actually received the parliamentary Premium appropriated to the Perſon who ſhould render ſo ſignal a Service to the World in general.

2. Far be it from me to envy the worthy Poſſeſſor the well-deſerved Reward of his indefatigable Labours; his Perſeverance for upwards of forty Years in the arduous purſuit of ſo important an object cannot be enough commended:

mended; and I heartily join his numerous Well-wishers in congratulating him on his Success. He must be allowed by all competent judges to have excelled every other Artist in compleating a *Time-keeper*, which, on repeated trials, hath answered the great purposes expected from it; and may it ever continue to do so! But who can engage that any Machine, though constructed on the nicest Rules of Art, shall never be out of order? And granting it moves invariably right, will its warmest abettors venture to assert that it has effected the Discovery of *every Thing* useful to the Mariner, so as to supersede all farther Enquiries, and to render them unnecessary? Has it, for instance, pointed out that great *desideratum* the Cause of the Variation of the Needle? Has it fixed, or shewn us where the first or grand Meridian is, or ought to be fixed; or indeed whether it is fixed at all? And if not, does it shew us how it is to be found, in order that the same Calculation of Longitude might serve all Nations? Many more Questions might be asked; but these are abundantly sufficient to convince us that farther Disquisitions on the Longitude cannot be justly deemed either useless, or unseasonable; for, as our methods of proceeding are on quite different Principles, it is impossible that what I have to offer in the following Pages should be anticipated or rendered unnecessary by Mr. *Harrison*'s Machine, even allowing it to be perfect.

3.

3. But ſince there are probably many, who do not well know what the *Longitude* means, it may be uſeful to ſubjoin a brief explication of it; (See Pl. IV. Fig. 1ſt. of the Appendix) where E, N, W, S, repreſent the Horizon; C, the Center; E, Æ, W, the Equator; P, the north Pole of the Equator: The ſeveral curve lines on each ſide of the Equator are called parallels of Latitude: The reſt of the curve lines which interſect the ſeveral Parallels of Latitude, and all of them at the Poles, are Meridians of Longitude, at 15 Degrees diſtance from each other, equal to an Hour in Time; and this leads me to point out how the Longitude may be diſcover'd by Time-keepers, ſuch as accurate Clocks, Watches, *&c.*

4. As every Circle, great or ſmall, contains 360 Degrees, and as the Sun in appearance compleats a Circle round us in 24 hours; ſay

ho. deg. ho. deg.

by the Rule of Proportion, If in 24 : 360 :: 1 : 15 — Then to find how much difference of Time is equal to a ſingle Degree of Longitude, it will be, if 15° be equal to 60' of Time, 1° will be equal to 4 Minutes of time; conſequently every ſingle minute of time is proportionable to a quarter of a Degree of a Circle; i. e. one fourth of a Degree of Longitude.

5. And as the Sun is in ſome Meridian or other to the Eaſt of London all the forenoon, and therefore before London in Time; conſequently it is to the Weſt in the afternoon, and therefore after London.

6. Suppose then, for instance, Mr. *Harrison* with his Time-piece sets sail from London, no matter at what time, provided his Time-piece be adjusted to the true time at that place.—— If, when he makes an observation of the time at any place, and finds it 8 minutes past 12 and at the same time finds by his own Clock or Time-piece it is just 12 in London, he may safely conclude himself 2 Degrees of Longitude to the East of London. Again,

7. Suppose after this he makes an observation of the time of Day or Night at any other place, and finds it 4 minutes past eight, and his Clock at the same time points out 56 minutes past 8 at London; that is more than at the place of observation by 52 minutes; as therefore every 4 minutes in Time is equal to a Degree of Longitude, and the Time at London being before that of the place of observation; if therefore 52 minutes be divided by 4, equal in proportion to a Degree of Longitude, it gives 13 Degrees of Longitude to the West of London. —— This is the method of finding the Longitude by Time-keepers, and the certainty of it depends upon the accurate construction of the Machine, in which Mr. *Harrison* has undoubtedly excelled every Artist that has gone before him.

8. Thus much being premised, I shall proceed directly to my point in view.

CHAP. II.

SECTION. 9.

The Cause of the Deflection *of the* Magnetic Needle *from the* Meridian.

THE magnetical Point or Pole, that is, the natural Agent or phyſical Cauſe of the Variation of the Needle, appearing ſometimes in the Meridian of the place of Obſervation and ſometimes out, is not only an undeniable proof that it is ſomewhere or other out of the Pole of the Equator, but an indication that it moves round that remarkable point, particularly as the Needle has appeared from obſervation to follow it from the Eaſt of the Meridian for 80 years, and towards the Weſt ever ſince, as will evidently appear hereafter. And as all remote Bodies in motion, except the Comets, appear to move in circular orbits, the ſame parity of reaſon may be ſuppoſed to hold good here alſo.—See Pl. IV. fig. 2d. which will convey a more adequate idea of it, than a multiplicity of words; where E, N, W, S, repreſent the Horizon of any place; C, at the Center, the place of Obſervation; N, C, S, the Meridian; N, the north part of the Meridian; S, the ſouth part; E, Æ, W, the Equator; P, the north Pole of the Equator; *a b p d e*, the Orbit in which the magnetic Point is ſuppoſed to move.

10. If then the magnetic Pole or moveable Point, makes a revolution in that Circle in any number of years, suppose 400; and as the north end of the Needle always directs to that moveable point, there will consequently be an almost perpetual (although very slow) variation, at every place, sometimes to the east of the North, at other times to the west.

11. To illustrate this.——Let us suppose the magnetic Point to be in the Meridian at (*a*), and if it move according to the order of the Signs, in 100 Years it will have compleated one quarter of its parallel of Latitude, i. e. it will then be arrived at *b*: But altho' it would then have kept varying to the west of the Meridian till it had past through one quarter of its parallel or orbit; yet it would not then appear at the farthest elongation with respect to the situation of the place of observation, as appears by the Figure. Nor can the Needle point out the greatest Variation till the governing Point be arrived at *p*, *viz.* to the Tangent C V, a considerable time after. At the expiration of 200 Years it would arrive at (*d*,) at the south part of the magnetic Circle: In like manner it would pass through all the eastern parts of the Orbit, *viz.* at 300 Years it would be at *e*; and in 400 Years at *a* again; that is, after varying to the East of the Meridian, it would then return to it again, in like manner as it did before, first from the Meridian to the West, and then from the West to the Meridian again.

CHAP.

CHAP. III.

SECTION 12.

Principles *on which the following* Theory *is founded.*

BEFORE I lay down my firſt Principles, which are, ſtrictly ſpeaking, only two, and ſuch, I perſuade myſelf, as will be thought unexceptionable, I muſt beg leave again to introduce that moſt reaſonable and uſeful Rule or Maxim of the celebrated Sir *Iſaac Newton*, which all Naturaliſts ſhould ever keep in their View, and that is, "*To admit no more Cauſes than what are "ſufficient to explain the Phænomena.* For "this purpoſe, Philoſophers (ſays he) aſſert "that *Nature does nothing in vain*;" or, in other words, all the Works of Nature are perfect.

13. Principle I. *That there is a certain* Point *called the* Magnetic-Pole, *to which the* Mariners Compaſs-Needle *perpetually tends or directs.*

II. *That the ſame* magnetic Agent *moves in a Circle or Orbit round the* Pole *of the* Equator.

14.

14. There are indeed not wanting, thoſe, who, when preſſed with the force of an argument againſt their own poſition, will deny almoſt every thing *, and produce many inſtan-

* I have, I confeſs, been informed, that my firſt Principle, undeniable as I might ſuppoſe it to be, would yet be denied by many; that is, they would not allow that there is any *Point, Pole, or Agent to which the Compaſs-needle tends.*

But can ſuch a *ſceptical Aſſertion* be admitted without ſome convincing Proof, ſince it ſtands contradicted by daily Experience? The tenacious tendency of the Needle towards the magnetic Pole is ſuch, that if the Navigator ſails into different Latitudes or to different Meridians, he ſoon finds a ſenſible difference in the variation of his Compaſs, and eſpecially if he ſails into a more northern Latitude: The north end of the Needle is ſo ſtrongly attach'd, or fix'd, as it were, to the magnetic Point or Pole, that ſuch end of it, appears ſuſceptible of every ſenſible change of Poſition, as is perpetually verified by a proportionable change of the variation of the Needle: And yet unleſs ſomething which evidently contradicts all theſe known *Facts* can be plainly made appear, the truth of this method of the diſcovery of the Longitude by means of the deviation of the Needle from the Meridian, amounts to little leſs than a *Demonſtration:* Were there not ſome Agent to influence the magnetic Needle ſo as to cauſe that polarity or northern tendency at all Times and in all Places, what advantage have the preſent Navigators beyond the former ones, i. e. thoſe who were before the polarity of the Needle was diſcover'd; for if what they aſſert be true, we have an effect produc'd without any real Cauſe; which is an abſurdity of the groſſeſt kind?

ces,

ces, which they imagine are proofs of their aſſertions, maintaining that many, even of the Works of the Creation, are very imperfect, and poſſibly inſtancing in the ſubject under our preſent Conſideration, inſiſting that from the general effects, it appears that the magnetic Poles were appointed for the ſole uſe of directing the Mariner to the ſeveral points of his Compaſs; and that as the north end of the Needle is conſtantly directed to the *magnetic* Pole, it would have been a much ſurer guide, if that point had been placed *in* the north Pole; for then the Needle always tending to the north, all the reſt of the points of his Compaſs would be accurately gained.

15. An arrogant and ſhort-ſighted *Alphonſus* might dare to aſſert, that had he been admitted into the Cabinet Council of Heaven at the firſt *Creation*, he could have mended the preſent Syſtem, and among other things might ſay, that as the Moon was created to illuminate the Earth by night, it ought not to revolve round the Earth as it does; ſince the conſequence of it is, that ſome nights the Earth is not illuminated at all; many others but little; and the Moon is no ſooner arrived to her Oppoſition to the Sun, where ſhe ſhines in her greateſt brightneſs and perfection, but ſhe keeps hurrying on towards her Conjunction, where ſhe is incapable of affording us any light at all.

16. Whereas inſtead of ſuch a monthly Revolution round us, had ſhe been placed in Oppoſition to the Sun, and endowed with ſuch a

par-

particular motion as would always have preferved her in that poſition, ſhe would then have much better anſwered the purpoſe, have enlighten'd us all the night long, and when the Sun was ſet, the Moon would always riſe, ſhining with her full face, and with undiminiſhed luſtre.

17. Here it muſt be owned, that in the manner the forementioned inſtances are ſtated, there ſeems to be a great impropriety, and therefore ſo far an imperfection in the Creation; and we may for that reaſon ſafely conclude that illuminating the Earth by night was not the ſole end for which the Moon was created*. — The ſame manner of Reaſoning will convince us, that an All-wiſe Being could never be guilty of ſo much abſurdity and impropriety, as to place out of the Meridian the only means intended to guide the Mariner to the points of his Compaſs; ſince that would be to defeat the very end propoſed: Nothing therefore can be a more certain ſign that the ſole uſe of the magnetic Pole was not to direct the Mariner to the points of his Compaſs, than its being placed *out of* the North Pole. The All-wiſe Author of Nature (as it now appears from the effects) placed it at a due diſtance from the Pole of the Equator with a much more extenſively benevolent intention than merely to direct him

* Philoſophers in general are of Opinion that the Moon is furniſh'd with Inhabitants, as well as the Earth.

to

to the ſeveral points of his Compaſs. By being placed at a due diſtance from the Pole of the Equator, that guide of the Mariner's Needle is equally capable of directing the Navigator to his Longitude as to the ſeveral points of his Compaſs, and with the ſame exactneſs as he now diſcovers his Latitude and Variation of his Needle, as will hereafter be explained.

18. When we view the Works of the Creation by halves, and draw concluſions too precipitantly, the moſt perfect operations of Nature may appear to us the moſt defective; whereas could we but ſee through the complicated ſcene, and view the well-connected ſyſtem together, and the orderly concatenation of the whole, the ſeeming imperfection would immediately vaniſh. What now might appear deformed, would then ſhine forth with all the beauties and graces becoming the exquiſite hand that formed it, and we ſhould then behold the ſeveral parts of the Creation, mutually aſſiſting each other in good Offices: Ex. gr. The Moon illuminating the Earth by night, and the Earth the Moon; and as the Earth is much the largeſt Body, conſequently a much greater light by night to the Moon, than that ſecondary Planet can be to the Earth, and doubtleſs the Lunarians may *fondly imagine* that the Earth, i. e. their Moon, was created merely to give them Light in their tedious night; eſpecially when we reflect on the ſtrange Phænomena that are there exhibited on account of the Moon

always keeping the ſame parts of it towards the Earth. Since every Aſtronomer well knows that their Moon, i. e. our Earth, for that reaſon, appears to thoſe Lunarians to be fixed as to its Altitude: To thoſe who poſſeſs the Center of the Diſk (as we term it) it appears fixed in their Zenith or vertical point; to the reſt of the Inhabitants, according to their different ſituation: All the motion of their Moon that they are ſenſible of, is a rotation on its Axis in the ſpace of 24 hours. In the middle of their day or year, the Sun is either north or ſouth of their Vertex according to the quantity of the Moon's Latitude. Their Day and Year are of the ſame length, *viz.* a lunar month: The Day their Summer, and the Night their Winter: The Quadratures their Spring and Autumn. If the Mid-day happen juſt at the time of the Node, they are totally eclipſed for a very conſiderable time, *viz.* an hour and three quarters at leaſt.—— Thus much may ſuffice to ſhew that we ſhould not too haſtily pronounce on the Imperfections of Nature's Works in any one inſtance, till we conſider what purpoſes beſides might poſſibly be ſerved by the ſame means in others, being ever convinced that the means by which ſhe brings about her ends are very extenſive; and though oftentimes beyond the reach of our ſhallow Underſtandings, yet when diſcoverd by us, they are always found to be ſtrictly conſiſtent with the above Principle, *viz. that Nature does nothing in vain.*

Illuſtration of the Firſt Principle.

19. The motion of the magnetic Pole round the Pole of the World has, before now, been thought the phyſical Cauſe of the variation of the Compaſs-needle, as plainly appears from Mr. *Derham's* Note on the Magnet; where he calls it a diſcovery of his own, deduced from ſome experiments and obſervations which he made, *viz.* that the magnetic Pole was endued with ſuch a motion as deſcribed a Circle of about 13 degrees Radius——That account being both inſtructive and entertaining, I ſhall tranſcribe the whole.

20. " Dr *Gilbert,* the moſt learned and accurate Writer on the Magnet, ſhews that its attractive virtue was known as early as *Plato* and *Ariſtotle*; but its direction was a diſcovery of later ages. He ſaith, "*ſuperiori ævo,* 300 *aut* 400 *labentibus annis, motus magneticus in boream & auſtrum repertus, aut ab hominibus rurſus recognitu fuit.*" De Mag. L. I. C. I. But who the happy inventor of this lucky diſcovery was, is not known. There is ſome not inconſiderable reaſon to think our famous Countryman, *Rog. Bacon,* either diſcover'd, or at leaſt knew of it. But for its uſe in Navigation, Dr. *Gilbert* ſaith, " *in regno Neapolitano Melphitani omnium primi (uti ferunt) pyxidem inſtruebant nauticam, edocti a cive quodam Jol. Goia.*" *A. D.* 1300, ibid. If the Reader hath a mind to ſee the arguments for the invention, being as old as *Solomon's* or *Plautus'*

 time,

time, or of much younger date, he may consult *Hakewill*, ib. C. X. Sect. 4. or *Purchas'* Pilgr. L. I. C. I. Sect. 1."

21. "As to the magnetic Variation, Dr. *Gilbert* attributes the Discovery of it to *Sebastian Cabott*. And the inclination of the dipping of the Needle was the discovery of our ingenious *Rob. Norman*. And lastly, the Variation of the Variation was first found out by the ingenious Mr. *H. Gellibrand*, Astr. Prof. of *Gresham-Col.* about 1634. Vid. Gellib. Disc. Math. on the Variation of the magn. Needle and its Variat. Anno 1635."

22. "But since that, the before-commended Dr. *Halley*, having formerly, in Philos. Trans. No. 148 and 195, given a probable Hypothesis of the Variation of the Compass, did in the Year 1700, undertake a long and hazardous Voyage, as far as the Ice near the South Pole, in order to examine his said Hypothesis, and to make a System of the magnetical Variations; which, being soon after published, has been since abundantly confirmed by the French, as may be seen in several of the late Memoirs *de Physique & de Mathematique*, published by the French Academie des Sciences."

23. "To these Discoveries, I hope the Reader will excuse me if I add one of my own, which I deduced some Years ago, from some magnetical Experiments and Observations I made; which Discovery I also acquainted our Royal Society with, some time since, *viz.* that

as the common horizontal Needle is continually varying up and down, towards the E. and W. ſo is the Dipping-needle varying up and down, towards or fromwards the Zenith, with its magnetic tendency, deſcribing a Circle round the Pole of the World, as I conceive, or ſome other Point. So that if we could procure a Needle ſo nicely made, as to point exactly according to the magnetic direction, it would in ſome certain number of years, deſcribe a Circle of about 13 deg. Radius * round the magnetic Poles northerly and ſoutherly. This I have for ſeveral years ſuſpected, and have had ſome reaſon for it too, which I mentioned three or four years ago at a meeting of our Royal Society; but I have not yet been ſo happy to procure a tolerable good Dipping-needle, or other proper one to my mind, to bring the thing to ſufficient teſt of experience; as in a ſhort time I hope to do, having lately hit upon a contrivance that may do the thing." Vid. Derham's Phyſic. Theol. p. 274. and 275.

Illuſtration of the Second Principle.

24. That the Needle, if of the beſt modern conſtruction, does, when impregnated, i. e. when properly touched with the Loadſtone, point out the magnetic Pole.——This Principle however needs no Illuſtration, all muſt allow it, ſince it is confirmed by daily experience;

* From later Obſervations, that Circle has been diſcover'd to be 13. deg. 51. min. nearly.

This

This is the Mariner's only dependance; for if the Needle ſwerve from *that*, he knows not how to find his North, nor conſequently any other point of his Compaſs; nay he would be in almoſt as bad a condition as before the directive property of the Loadſtone was diſcover'd.

25. There is another Thing which is abſolutely neceſſary to be known; but that may be obtained by the following Problem.

The Problem.

26. Having the Latitudes and the difference of Longitudes of any two places accurately obtained, by the obſervations of the Immerſions or Emerſions of Jupiter's Satellites, together with the Variation of the Needle at each place; to find from thence the Latitude of the common point of interſection of the variation lines, that being the true Latitude of the magnetic Pole, which by that means appears to be 76 deg. 9 min. conſequently the Complement is 13 deg 51 min. equal to the true diſtance of the magnetic Pole from the Pole of the Equator. —— This is the diſtance I ſhall make uſe of, ſince it is found ſtrictly to agree with Calculation, as will very ſoon appear.

CHAP.

CHAP. IV.

SECTION 27.

DEFINITIONS.

Magnetic MERIDIAN.

THIS is that particular Meridian *that is at any time possessed by the magnetic Pole; which according to the* present Theory *is the only Line of no Variation that can happen.*

The common *Definition of the* Magnetic Meridian *is, that it is a great Circle passing through, or by the magnetical Poles, to which the Mariner*'s *Needle (when not otherwise prevented) always conforms itself: Or, in other words, it is the Circle pointed out by the Compass-needle.*

But as that Circle has a great affinity to an Azimuth-circle in Astronomy, I shall take the liberty of calling it the *magnetical Azimuth*, that so the Term may be expressive of the thing meant, like other Terms.

Many of the Phænomena of Nature are so abstruse and perplexing, that the Persons who first attempt the solution of them are seldom happy enough to succeed; and even after forming many ingenious Hypotheses for that purpose, and spending Years in indefatigable and labo-

laborious purſuit of the Object they had in view, have yet failed to attain it: This is moſt notoriouſly verified in the Caſe of the celebrated Dr. *Halley*, as I ſhall now ſhew.

28. The firſt who attempted to make any conſiderable uſe of the Variation of the magnetic Needle, at leaſt ſo far as to correct the Longitude by that means, was the learned and indefatigable Dr. *Halley*, whoſe Sentiments on that ſubject we find in Mr. *Baddam*'s Abridgement of the Philoſ. Tranſ. Vol. III. p. 25. intitled " The *Cauſe of the change of the Vari-* " *ation of the magnetical* Needle, *with an Hypo-* " *theſis of the Structure of the internal parts of* " *the Earth*; by Mr. *Edm. Halley*, Phil. Tranſ. " No. 195. p. 563." Where Mr. *Baddam* obſerves, That

29. " Mr. *Halley*, in his Theory of the Variation of the magnetical Needle, came at length to this general concluſion; *viz.* that the Globe of the Earth might be ſuppoſed to be one great Magnet, with four magnetical Poles or points of Attraction, two of them near each Pole of the *Equator*; and that in thoſe parts of the world, which lie near any of thoſe magnetical Poles, the Needle is chiefly governed thereby, the neareſt pole being always predominant over the more remote; and he there endeavoured to ſtate and limit the preſent poſition of thoſe poles on the ſurface of our Globe; yet he found two difficulties not eaſily to be ſurmounted; the one was, that no Magnet, he had ever

ſeen

feen or heard of, had more than two oppofite poles, whereas the Earth had vifibly four, and perhaps more; and fecondly, it was plain, that thefe poles were not, at leaft all of them, fixed in the Earth, but fhifted from place to place, as appeared by the great changes in the needle's direction within this laft century of years; not only at *London*, where this great difcovery was firft made, but almoft all over the Globe of the Earth; whereas it is not known, or obferved, that the poles of a Loadftone ever fhifted their place in the ftone, nor, confidering the compactnefs of its fubftance, can it eafily be fuppofed."

30. "Thefe difficulties made the Author quite defpair of ever being able to account for this phænomenon, when in an accidental converfation he lighted on the following hypothefis: It is fufficiently known and allowed, that the variation of the needle changes, but that this change is gradual and univerfal will appear by the following examples. At *London* in 1580 the variation was obferved by Mr. *Burrows* to be 11 deg. 15 min. to the eaft: In 1622, the fame was found by Mr. *Gunter* to be only 6 deg. to the eaft: In 1634, Mr. *Gellibrand* obferved it 4 deg. 5 min. to the eaft: In 1657, Mr. *Bond* obferved that there was no variation at London: In 1672, Mr *Halley* himfelf obferved it 2 deg. 30 min. to the weft; fo that in 112 years the direction of the Needle has changed no lefs than 17 degrees." From thefe and many other

observations it is evident, that the direction of the Needle is in no place fixed and constant, though in some it changes faster than in others; and where for a long time it has continued, as it were unalterable, it is there to be understood, that the needle has its greatest deflection, and is become stationary, in order to return, like the Sun in the Tropics."

31. "The period of this motion being wonderfully great, and there being hardly a century since these variations have been duly observed, it will be very hard to bring this hypothesis to a calculus, especially since, though the variations do increase and decrease regularly in the same place, yet in different places, at no great distance, there are found such casual changes thereof, as can no ways be accounted for by a regular hypothesis, as depending upon the unequal and irregular distribution of the magnetical matter within the substance of the external shell or coat of the earth, which deflects the needle from the position it would acquire from the effect of the general magnetism of the whole; of this the variations at London and Paris afford a notable instance; for the needle has been constantly about a degree and an half more easterly at Paris than at London, though it be certain, according to the general effect, the difference ought to be the contrary way *, notwithstanding which, the variations

* This will be found to be a palpable Mistake, when I come to treat farther on the Longitude.

in

in both places do change alike." P. 27. 28. of Mr. *Baddam*'s Abridgement.——A little farther on Dr. *Halley* appears to despair of ever investigating a Theory of the Variation from all his observations; his words are——"The whole period thereof, is performed in 700 years or thereabouts; so that the nice determination of this, and of several other particulars in the magnetic system is reserved for later posterity." P. 29.

32. Here we find that the *Doctor*'s Plan, which admitted of 2 north and 2 south Poles, proved utterly incapable of affording the assistance requisite to enable him to form a regular Hypothesis whereby to investigate the periodical Revolution of the magnetic Pole: Whereas the present Plan, which allows of but one north magnetic pole, and that pole to move in a Circle or Orbit, affords sufficient means to trace out the time of a *periodical Revolution*, and consequently its *yearly motion*: From these requisites its distance may be readily discover'd at all times from any given place, which is an advantage not to be attained by any other method.——By moving thus regularly in an Orbit, Dr. *Halley*'s Observation is confirmed, *viz.* that when the variation appears for a long time unalterable, it is then near the time of its greatest variation.——This is obvious by Inspection at Pl. IV. fig. 2d or 3d. when near the Tangent C *v*. And in a word, by allowing the magnetic Pole to move regularly in a

Circle, like other remote Bodies in motion, all the different Phænomena are ſolved in a natural way, even that heretofore unſurmountable one which perplexed the ſubject the moſt of all, namely, where, after the *Doctor* had been enumerating the great difficulties, he adds, *of which the variations at* London *and* Paris *afford a notable inſtance; for the Needle has been about a degree and an half more eaſterly at Paris than at London, though it be certain, according to the general effect, the difference ought to be the contrary way.* That is, he thought the Weſt variation ought to be greateſt at *Paris.*

N. B. This is ſo far from being ſuch a Paradox as he imagined, that when the magnetic Pole is allowed to move regularly in a Circle round the Pole of the Equator, that Phænomenon becomes a natural and neceſſary conſequence of its ſituation, as may be ſeen in 2 following Calculations.

33. It is an obſervation worthy our notice, that many of the moſt principal diſcoveries in Philoſophy have been really, as it were, fortuitous; by which, I mean not to impute them to blind chance, but to the ſecret unſeen Hand of divine Providence, which often ſurprizes us with benefits beyond our moſt ſanguine expectations.— To that ſupremely benevolent Cauſe, I do gratefully attribute the inſtantaneous, and (may I not call it?) miraculous Revelation of the ſubtile Medium to Profeſſor *Muſſchenbroek*, by which a Key has been given us,

where-

wherewith to unlock the Secrets of Nature, and to account rationally for her Operations. ——That which the worthily celebrated Sir *Isaac Newton* so earnestly, yet unsuccessfully sought for, was discover'd to Professor *Musschenbroek* in form of a mere Accident——And here by way of digression I must remark,

34. That Dr. *Halley*, when endeavouring to write a regular Theory of the variation of the Mariner's Compass-needle, met with so many perplexing difficulties, that he was of opinion, it was not capable of being reduced to any regular Hypothesis.——And this will be always the case, if we found it upon observations made promiscuously, in different Latitudes and in different Meridians: As to the difficulties arising from the great length of a periodical Revolution, it may be shorten'd by parallel sailing, that is, by sailing in the same parallel of Latitude towards the magnetic Pole, and making observations of the variation at different parts of it, and carefully noting them down and comparing them; there would from thence immediately appear the same regularity, as if we were to wait at home for many years to make the same observations. In either of these cases, we should meet with regularity, especially if we admit of but one north magnetic Pole, and allow it to move round the north pole in a parallel of Latitude; some things by analogy might also then be produced. This however is certain, that no regular Calculus can be made

with ſucceſs, that is, ſuch as might be depended on, unleſs after proper obſervations at the ſame place, we have an opportunity of beginning the calculation at the Meridian of that place.

35. The uſe I would make of this digreſſion is to illuſtrate the above poſition, *viz.* by ſhewing that all theſe neceſſary requiſites are *ready at hand.* The obſervations of Meſſrs. *Burrows, Gunter, Gellibrand,* and *Bond,* though the firſt that we find taken notice of, and thoſe ſeeming merely accidental; yet have they all the plaineſt marks of deſign; ſince more proper points of time or places in its Orbit could not eaſily have been fixed on.——And had not the magnetic pole been eaſt of the meridian, when thoſe ſeveral obſervations were made, they had been much leſs capable of exhibiting ſuch regular and convincing marks as they do of the truth of the Hypotheſis which I am now labouring to eſtabliſh; and indeed unleſs their obſervations had commenced before the magnetic pole had paſſed the meridian, I ſhould now be entirely at a loſs for a proper point where to begin my calculation: So that here was every neceſſary requiſite *provided*; and yet all had the appearance of the effects of only *mere chance.*

36. In 1672, Dr. *Halley* himſelf made an Obſervation of the variation and found it 2 deg. 30 min. to the *Weſt* of the Meridian of London; and from this obſervation of his, I had reaſon, on repeated calculations, to conclude that

the

the precise Time of no Variation at that place was about 12 years before, *viz.* in 1660, or nearly.

37. But as this observation of the *Doctor's* pointed out the year 1660 for the time of no variation in the Meridian of London, and as it was too late for Mr. *Bond's*, who thought the Needle had no variation in the year 1657, I was of opinion that the truth would be fixed on a more firm basis by comparing Dr. *Halley's* Observation taken almost a century ago, with one of a more recent date, made by the late ingenious Dr. *Bradley* *. An Apparatus of the most improved Instruments, which those Gentlemen enjoyed at the Royal Observatory, contributed not a little to the accuracy of those Observations. What I shall now refer to is that of the *Doctor's* made in the year 1750, when the variation was 17 deg. 25 min. delineated on Pl. IV. fig. 3d. of this Appendix, and explained in the following Section. Where

38. W, N, E, S represent the Horizon of the Royal Observatory near London, C the center or place of Observation, N S the Meridian, W Æ E the Equator, P the Pole of the Equator, as before.

Secondly, The little Circle *a m b p d e* is the parallel of Latitude wherein the magnetic pole moves, equal to 76 deg. 9 min. whose complement is 13 deg. 51 min. equal to the Radius *m* P or distance of the magnetic pole

* See the last page of Messrs. *Mountaine* and *Dodson's* account of their large Sea Chart.

or

or point, from the pole of the Equator.—— The circle H G K C repreſent the parallel of Latitude of the Royal Obſervatory.

Thirdly, The 2 Tangents to the magnetic Orbit ſhew the greateſt Weſt and Eaſt Variation: The other lines contained within thoſe limits ſhew the ſeveral Variations, and the different times when each of the Obſervations were made. The number of degrees and minutes of Variation are thoſe on the Horizon at the end of the ſeveral lines.

Fourthly, The Triangle C P *m* is adapted to the Obſervation of Dr. *Bradley* when the Variation was 17 deg. 25 min. as above.

Problem.

39. ¶ To find the Longitude of the magnetic Meridian in 1750 when the *Doctor* made his Obſervation.

Having 1ſt. the comp. of the Latitude of that place C P equal to 38 deg. 31 min 30 ſec.

2dly. The Angle of Variation P C *m* equal to 17 deg. 25 min.

3dly. The Side P *m* equal to the comp. of the Latitude of the magnetic Pole equal to 13 deg. 51 min. To find the Angle C P *m*,

By the univerſal Propoſition it will be

As the cotan. of the ∠ C	$17^\circ\ 25'$ -	10.503485
To the cs. of the ſide C P	38 31 30	9.893393
So is Rad. — — — —		10.
To the cotan. of the ∠ C P *o*	$76^\circ\ 13'$	9.389908

Then

Then to gain the Angle m P o it will be

As the ct. of the comp. of the Lat. CP 38° 31′ 30″	10.099006
To the co-ſine of CPo 76° 13′	9.377035
So is the ct. of Pm 13° 51′ = the comp. of Lat. of mag. pole	10.608097
To the co-ſine of m P o 39° 42′	9.886126

The ſum of 76° 13′ + 39° 42′ = 115° 55′ = the ∠ CP m = the Longitude of the magnetic pole from the place of obſervation, *viz.* from the Royal Obſervatory in the Year 1750.

Then,

40. From the Longitude of the magnetic pole in the Year 1660 = $ambpd$ = 180° 0′, ſubtract 115° 55′ as above = $mbpd$, the remainder is = 64° 5′ = am.

41. The ſpace of time taken up by the magnetic pole in its progreſs from a to m in its Orbit = 64° 5′ was 90 Years; *viz.* from the Year 1660 to the Year 1750; that is, to the time when the Obſervation of the variation was made by Dr. *Bradley* at the Obſervatory aforeſaid.

42. Then to find the time of the periodical Revolution of that point or pole, it will be thus: If 90 Years : 64° 5′ —— Or rather by being converted into minutes = 3845, ſay,

43. If 3845 minutes of degrees require 90 Years; 360 deg. or 21600 min. will require 505 years 215 days 8 hours and 24 minutes.

44. To find its yearly motion, ſay, If 90

Years : 3845 minutes of its Orbit : : 1 Year will be equal to 42′ 43″ 20‴.

45. Having by the laſt Problem, from the given Variation found the Longitude of the place of Obſervation from the magnetic Meridian, and from thence deduced its periodical Revolution and yearly motion, I ſhall next ſhew that by having its Longitude given in any given parallel of Latitude, the Variation of the Needle from the Meridian may be found for any paſt or future year.——I ſhall illuſtrate that Problem with a variety of Examples at different times, and ſhall begin my calculation at the Year 1660, and attend the ſubterraneous agent till it has paſſed half through its Orbit, namely, from *a* to *m b p* and *d*, equal to 180 degrees, that is, till it be arrived at the hithermoſt part of its Orbit at *d*.

46. And ſince Meſſrs. *Mountaine* and *Dodſon*, in the account of their large Chart abovementioned, inform us, that the change of the Variation is ſo exceeding tranſient, that it is neceſſary to renew it every 10 or 12 years, I have therefore renew'd my calculation at every 10 Years end : But here it is neceſſary for me in the firſt place to ſhew, how far the magnetic Pole proceeds in its orbit in that time which is found by the ſame proportion, thus :

As 90 Years is to 64° 5′ ſo is 10 Years to 7° 7′ 12″.

47. The given place, or Longitude of the magnetic pole in its orbit at *a*, ſee fig. 3d. Pl. IV.

IV. is equal to 180 degrees from C, the place of Obſervation.——That Pole in 10 Years time, *viz.* in 1670 had proceeded forward 7° 7′ 12″ from the Meridian, and was two Years before Dr. *Halley* made his Obſervation on the Variation; ſince therefore 7° 7′ 12″ is found juſt by computation, I ſhall proceed in the following manner;

48. From 180 degrees ſubtract the aforeſaid number of degrees minutes and ſeconds for the firſt 10 Years, and the remainder is 172° 52′ 48″. This therefore was the weſt Longitude of the magnetic Pole in 1670; conſequently then,

49. The 3 Things given are, 1ſt. the complement of Latitude = CP 38° 31′ 39″. 2dly. The complement of Latitude of the magnetic Pole P*m* = 13° 51′. 3dly. The ∠ CP*m* = 172° 54′ 28″ of Longitude of that Pole from the place of Obſervation; and thus the Longitude is aſſumed at every ſucceeding operation; and from thence the quantity of the Variation is diſcover'd: The given *Data* being always the Angle of Longitude and the 2 ſides including it, I ſhall make uſe of Mr. *Oughtred*'s Axiom, which ſolves that Problem without a perpendicular, by the following proportion.

As the Sine of half the Sum of two Sides, to the ſine of half their difference; ſo is the Co-tangent of half the contained Angle, to the Tangent of half the difference of the other Angles.

Again,

As the Co-ſine of half the ſum of the ſides, to the Co-ſine of half their difference; ſo is the Co-tangent of half the contained Angle, to the Tangent of half the ſum of the other Angles.

The given ſides of the Triangle as before obſerved are,

The comp. of the Lat. of the Obſervatory CP 38° 31′ 30″

And the comp. of the Lat. of the magnetic Pole Pp 13° 51′.

Whoſe Sum is	52° 22′ 30″
The half Sum	26° 11′ 15″
The difference	24° 40′ 30″
The half difference	12° 20′ 15″

Then it will be,

As the s. of ½ the ſum of the 2 ſides 26° 11′ 15″. Arith. Comp.	0.355256
to the s. of ½ their differ. 12° 20′ 15″	9.329743
So is the ct. of ½ the contain'd ∠ 86° 26′ 24″	8.793462
to the t. of ½ the difference of the other 2 ∠s 1° 43′ 30″	8.478461

And,

As

As the cs. of half the sum of the 2 sides $26^\circ\ 11'\ 15''$ Ar. Comp. } 0.047067
to the cs. of $\frac{1}{2}$ their diff. $12^\circ\ 20'\ 15''$ 9.989839
So is the ct of half the contained ∠ $86^\circ\ 26'\ 24''$ — — } 8.793462

to the tan. of half the sum of the other 2 ∠s $3^\circ\ 52'\ 30''$ } 8.830368

Half difference $1^\circ\ 43'\ 30''$ to be added and subtracted

their Sum $5^\circ\ 36'$ = the greatest ∠.

their difference $2^\circ\ 9'$ = the least ∠ = Variation.

So that in 10 Years time, i. e. in the Year 1670, the Variation at the Royal Observatory was $2^\circ\ 9'$.

The degrees of Longitude for the next 10 Years, *viz.* 1680, will be $172^\circ\ 52'\ 48''$ less $7^\circ\ 7'\ 12'$ is = $165^\circ\ 45'\ 36''$.

Then the Calculation will be,

As the s. of half the sum of the 2 sides $26^\circ\ 11'\ 15''$ Ar. Comp. } 0.355256
to the s. of $\frac{1}{2}$ their diff. $12^\circ\ 20'\ 15''$ 9.329743
So is the ct. of half the contained ∠ $82^\circ\ 52'\ 48''$ — — } 9.097105

to the tan. of half the difference of the other 2 ∠s $3^\circ\ 28'$ — } 8.782104

And,

As

As the cs. of half the sum of the 2 sides — Arith. Comp.	}	0.647067
to the cs. of half their difference		9.989839
So is the ct. of half the contained ∠ 82° 52′ 48″ — —	}	9.097105
to the tan. of half the sum of the other 2 ∠s 7° 45′ —	}	9.134011

11° 13′ = the greatest ∠

4° 17′ = the ∠ of Variat.

50. If this operation be repeated for every 10th Year, by thus assuming the Longitude or distance of the magnetic Meridian from the Meridian of the place of Observation, the Variation is discover'd in an easy and natural manner: The following Table was constructed by thus deducting 7° 7′ 12″ from the Longitude at every Operation.

Yrs.	Longitude. Deg.	m.	s.	Variat D.	m.
1660	180	0	0	0	0
1670	172	52	48	2	9
1680	165	45	36	4	17
1690	158	38	24	6	22
1700	151	31	12	8	26½
1710	144	24	0	10	26
1720	137	16	48	12	21
1730	130	9	36	14	9
1740	123	2	24	15	51

Yrs.	Longitude. Deg.	m.	s.	Variat D.	m.
1750	115	55	12	17*	25
1760	108	48	0	18	49
1770	101	40	48	20	3
1780	94	33	36	21	4
1790	87	26	24	21	51
1800	80	19	12	22	22
1810	73	12	0	22	36
1820	66	4	48	22	28
1830	58	57	36	21	59
1840	51	50	24	20	49
1850	44	43	12	19	39
1860	37	36	0	17	45
1870	30	28	48	15	19
1880	23	21	36	12	23
1890	16	14	24	8	57
1900	9	7	12	4	56
1910	2	0	0	1	9
1912½	0	0	0	0	0

51. The foregoing Table ſhews that the ſeveral Variations of the Needle from the Meridian when the magnetic Pole is at the farther part of its Orbit, conſtantly decreaſe in quantity till the magnetic Pole arrives at the place of the Tangent p, which is evident by the ſeveral Variations, and after that increaſe again.

52. By which method of proceeding, it appears that between the Years 1912 and 1913

* It is worthy of remark that Dr. *Bradley*'s Obſervation of the Variation for the Year 1750, *viz.* 17° 25′ came out juſt, to the very minute, altho' at the 9th Operation, the

the Mariner's Compaſs-needle will have no Variation, nor the magnetic Pole any Longitude at the Meridian of London, or at the forementioned Obſervatory, both of them being nearly in the ſame Meridian, and within a few minutes of the ſame parallel.

53. If it be objected that my firſt operation is contradicted by the laſt, ſince 7° 7′ of the magnetic orbit at the former, produces but 2° 9′ of variation; whereas at the latter, the ſame number of degrees difference of Longitude from that point, makes almoſt 4 degrees of Variation.

54. I anſwer: This will appear to be but a natural and neceſſary conſequence, if we conſult the 20th propoſition of the 3d Book of Euclid; where it is demonſtrated, that the ∠ at the center of a Circle is double the quantity of the ∠ at the circumference, &c. 7 deg. 7 min. &c. therefore of the magnetic orbit at *d*, at the diſtance of C*d*, muſt produce an ∠ of almoſt double the quantity that would be produced from that number of degrees at the diſtance of C*a*.

55. I ſhall now, by way of illuſtration, ſet down the ſame numbers back again, from the Meridian at the neareſt part of the ſame parallel of Latitude at *d*, till the magnetic agent has paſſed through the eaſtern part of it; in which all the ſame Phænomena will be exhibited as before in the weſtern, but in an inverted order.

The

The Longitude of the magnetic Pole, and Variation of the Compaſs-Needle from the *neareſt* part of the magnetic Orbit, and from thence through the eaſt part of it.

Yrs.	Longitude: Deg.	m.	ſ.	Variat D.	m.
1912½	0	0	0	0	0
1915	2	0	0	1	9
1925	9	7	12	4	56
1935	16	14	24	8	57
1945	23	21	36	12	23
1955	30	28	48	15	19
1965	37	36	0	17	45
1975	44	43	12	19	39
1985	51	50	24	20	49
1995	58	57	36	21	59
2005	66	04	48	22	28
2015	73	12	0	22	36
2025	80	19	12	22	22
2035	87	26	24	21	51
2045	94	33	36	21	4
2055	101	40	48	20	3
2065	108	48	0	18	49
2075	115	55	12	17	25
2085	123	2	24	15	51
2095	130	9	36	14	9
2105	137	16	48	12	21
2115	144	24	0	10	26
2125	151	31	12	8	26½
2135	158	38	24	6	22
2145	165	45	36	4	17
2155	172	52	48	2	9
2165	180	0	0	0	0

56. The following is that Obſervation of Dr. *Halley*'s of the Variation of the magnetic Needle made at London in the Year 1672, 12 Years after the Æra of commencement of the time and place of the preceding Calculation; and is an illuſtration of the foregoing Theory, which it is preſumed will be allowed to ſtrengthen it, by finding how nearly it coincides with the principles on which my calculations are founded.

57. As 90 years to 64° 5′, or by converting it into minutes as before; As 90 years to 3845′ of ſpace, gained in the magnetic Orbit; So is 12 years, [equal to the ſpace of time, ſince the year 1660] to 512,666′ or 8° 32′.

58. Then if 8° 32′ be ſubducted from 180° there will remain 171° 28′ equal to the Longitude of the magnetic Pole from the Meridian of the Royal Obſervatory, the half of which is 85° 44′.

59. To find what was the Variation of the Needle in 1672.

As the s. of half the ſum of the 2 ſides = 26° 11′ 15″ Ar. Comp.	0.355256
to the s. of half their diff. 12° 20′ 15″	9.329743
So is the ct. of half the contained ∠ 85° 44′ — — —	8.872770
to the tan. of half the diff. of the other 2 ∠s 2° 4′ — —	8.557779

And,

As

As the cs. of half the ſum of the ſides Arith. Comp.	0.047067
to the cs. of half their difference	9.989839
So is the ct. of half the contained ∠ 85° 44′	8.872770
to the tan. of half the ſum of the other 2 ∠s 4° 37′	8.909676

Half diff. of the other 2 ∠s 2° 4′

their Sum = 6° 41′ the greateſt ∠

their Difference = 2° 33′ the leaſt ∠ = the Variation.

Hence it appears by Calculation that the Variation in the Year 1672 was 2° 33′; and hence alſo it appears that 1660 was the Year of no Variation in London; ſince by the *Doctor*'s Obſervation, the Variation was 2° 30′; and an Error of two or three Minutes is eaſily committed in ſuch kind of Experiments.

60. When I view the preceding Table and behold the regularity and perſpicuity of what is there exhibited, with reſpect both to the Longitude and the Variation, I feel a ſecret pleaſure to think that *I ſhould be ſo happy as to ſtumble* on a method to reduce that which hath hitherto been thought productive of the greateſt irregularities and moſt complicated Phænomena in all Nature, to ſuch a perfect regularity, as to render it equally beautiful and harmonious in its effects with the reſt of Nature's operations; and this, by only allowing the cauſe of the polarity or

directive property of the Needle, i. e. *the magnetic Pole*, to have ſuch a particular motion as, in fact, it really appears to have, *viz*. a revolution round the Pole of the Equator.

61. But this remarkable regularity, with which I ſeem ſo highly pleaſed, and on which I place ſo great a ſtreſs, may very probably be made by others a principal Objection againſt the truth of my whole Scheme, ſince nothing but the reverſe of all this, ever appeared to them; which indeed will inevitably be the caſe when Obſervations are made promiſcuouſly, in different Latitudes and different Meridians, as they generally are.——It may probably be objected likewiſe, that tho' it be eaſy enough to form a Table on ſuch Principles; yet that the great Dr. *Halley* ſays, that the irregularities attending the Theory of the Variation are ſo great as to render it almoſt impoſſible to bring it to any regular Hypotheſis: The periodical Revolution, for inſtance, is ſo great, that he tells us, *the nice determination of that and many other particulars in the magnetical Syſtem is reſerved for later Poſterity*.

62. Indeed the difficulties attending Obſervations of the Variation muſt be allowed to be unſurmountable, as I obſerved before, ſo long as we have no regard either to different Latitudes or different Meridians; and as he juſtly obſerves, waiting at the ſame place to compleat a Theory is impracticable.

63. As I cannot flatter myſelf with the good fortune

fortune of efcaping Objections to my Affertions, which ever attend thofe who ftrike out new, though plainer paths to truth than had been before difcover'd; I fhall here endeavour to ftate all the moft material Objections and place them in their ftrongeft light, and try if they are not to be obviated. And Firft, I fhall fuppofe all the abovementioned difficulties which might be objected from Dr. *Halley*'s different Sentiments on this fubject.

64. That fo impotent and inconfiderable an Obferver as the Author fhould ftrike out fome kind of regularity, where fo great a Man as Dr. *Halley* could obferve none, is fomething remarkable; and whenever I reflect on it, it generally brings to my mind, the Obfervation of the ingenious Mr. *Jones*, fo lately taken notice of, *viz*. that a much ftronger Likenefs hath fometimes been hit by an indifferent Painter, than at other times by the greateft Proficients in that Art: Every one knows how to make the Application. It would therefore favour much of Ill-nature, were any one to reprefent me affuming and arrogant enough to prefume to vie with one fo much fuperior in natural and acquired Abilities, as Dr. *Halley* moft certainly was.

65. Indeed had he allowed of but *one* north magnetic Pole inftead of *two*, and that Pole to move in a parallel of Latitude; that is, had not our Schemes been different, he never would have affirmed that by reafon of the great length

of

of the period it was incapable of a nice determination till ſucceeding Ages, intimating thereby, that one age was much too ſhort a ſpace of time to make proper obſervations to examine it: For had he believed it to move in a parallel of Latitude, he muſt have known that the effects would be equal, and all the different Phænomena the ſame, whether we wait at one place till the magnetic Pole approached nearer to our Meridian any number of degrees in its parallel; or whether we ſhould advance nearer to the magnetic Meridian the ſame number of degrees in our parallel.

66. Had we an open Sea entirely ſurrounding the Globe in the parallel of London for inſtance; that period of the magnetic Pole which would require the obſervation of 505 Years at London, might, by an eaſy rate of ſailing in the ſame parallel, be accompliſhed in the ſame number of Days; and all the different appearances exhibited in the Table both of the Variation and Longitude made for every 10 Years would, at the ſame eaſy rate of parallel ſailing, be compleated in 10 Days.

67. According to the preſent Theory thoſe who are living in London in the Year 1912, *viz.* 146 Years hence, will have no Variation of the Needle from the Meridian; the magnetic Pole will by that time be arrived to it; and *that* Meridian will therefore then become the magnetic Meridian, and the Needle by pointing towards that Pole can conſequently have no

Varia-

Variation; but the Mariner by sailing *to* the present magnetic Meridian would have all the different Appearances in 146 Days, and, by being then in the magnetic Meridian, would, like the former, have no Variation. Again,

68. As the magnetic Pole after its arrival to the nearest part of its Orbit, *viz.* at *d*, will be passing on to the east, and will consequently cause an east variation at that place; so the Mariner having attained the magnetic Meridian, where his west variation would end *, he,

* It will not be improper to observe here, that the Mariner who should perform such a Voyage by parallel sailing in the Latitude of London, would not find his west Variation gradually to decrease from the time of first setting out toward the West: If we consult the Table, we shall find, that according to the present Theory, the West Variation is still increasing at London, and so will continue till the Year 1810, *viz.* 44 Years to come, that being the Time when the magnetic Pole will meet with the Tangent, (See Plate IV. Fig. 2d. 3d.) where the greatest Variation happens in that Latitude, and the Longitude of London at that Time from the magnetic Meridian will then be about 72 deg. to the West, after which Time, the Variation will begin to decrease; and consequently the Navigator for the same reason must sail westward for 44 days, when the Variation would be increasing till that Time; and then he would likewise be about 72 deg. of Longitude from the magnetic Meridian, and would there find his Variation to be 22° 36′, *viz.* the greatest Variation in that parallel: After which it would be constantly lessening till he arriv'd at the same Meridian.

by

by ſtill ſteering his courſe to the *weſt* of the magnetic Meridian, will neceſſarily have an *eaſt* variation; but this is too obvious to need any farther explanation.

69. It may alſo be objected, that not one of the Obſervations made (whilſt the Needle had an eaſt variation) by Meſſrs. *Burrows*, *Gunter*, *Gellibrand* and *Bond*, agree with my periodical motion of the magnetical Pole; ſince the period of time between the firſt and laſt of them, *viz.* Mr. *Burrows* and Mr. *Bond* was 77 years, that is, from 1580 to 1657, during which time the Variation altered no more than 11° 15′, which differs conſiderably from Dr. *Halley*'s and Dr. *Bradley*'s Obſervations, upon which this Theory is founded.

70. All this I muſt own to be true; and the only probable means of accounting for ſo remarkable a difference is to conſider it as the effect of the badneſs of our *common* Compaſs-needles, ſome of which, I am convinced, will reſt at 8 or 9 degrees ſhort of, or beyond the place where they ought to reſt. And I ſpeak from experience, thoſe I generally made uſe of, which were of the common conſtruction, inſtead, for inſtance, of ſtopping at 19 or 20 degrees to the weſt of the Meridian more frequently reſted at 27 or 28 degrees, and I have but ſeldom found them to ſtop twice at the ſame point.

71. My reaſon for preferring Dr. *Halley*'s Obſervation of 1672, when the Variation was

2° 30′ to the weſt, and Dr. *Bradley's*, made 1750, who found it to be at that time 17° 25′ to the ſame direction, is the ſtriking agreement I obſerved in the Obſervations of thoſe two great Men; to which let me add the probability of their being accommodated at the Royal Obſervatory with the beſt of Inſtruments, formed certainly on a more accurate conſtruction than thoſe might be, which were uſed by Mr. *Burrows*, *Gellibrand*, *&c.* almoſt two Centuries ago.

72. I have indeed heard ſome Mariners aver, that the Compaſs-needles vary ſo much from each other, that there can be no ſort of certainty of finding out the true Longitude from their direction, and have aſſured me that where ſeveral Ships are in Company, the directive property of each Compaſs-needle is generally found to be widely different.——But what more does all this amount to than that their Needles are ſo faulty as not to be depended upon; and I cannot help repeating here my former Interrogation, that if there be no point to which the Compaſs-needle is *always* directed, what advantage has the preſent Navigator more than he, who lived before the Magnet was known?

73. And if this be the caſe with the common Compaſs, it is no wonder the Mariner ſeldom obtains the ſeveral points of it to any tolerable degree of exactneſs: Beſides, the loading of the Needle with the Compaſs on its back, muſt be no ſmall impediment to the free

ſuch a line through the center, as may biſect the Circle between thoſe two points, and that line is a true Meridian, *viz.* a line that points truly north and ſouth.——I have one of theſe meridian Lines, which I made by the following method. I deſcribed ſeveral concentric Circles and erected a perpendicular in the center, of ſuch an height that the ſhadow of the vertex might be capable of interſecting them all, to remedy the inconveniency of being oftentimes diſappointed by Clouds, either at the ſhadow's paſſing into, or out of the Circle. The ſhadow of that vertical point of the perpendicular I traced by marking it from the morning to the afternoon at proper intervals of time, till it had paſſed over all thoſe Circles; ſo that if it happen'd to be cloudy, when the ſhadow would have paſſed any one of them, it was eaſily remedied by compleating the path of the ſhadow of the vertex. After this, when I had biſected the ſeveral Circles, and marked them, I found them ſo accurate, that when a line was drawn through the center, and through the biſecting mark of the outermoſt Circle, the ſame line paſſed through the other biſections, which was a ſatisfactory proof that the line was juſtly drawn; thoſe irregularities, that ſeem'd, in the ſeveral biſecting points, ſcarcely perceptible, I corrected by endeavouring to paſs my Meridian through the midſt of them.

78. This Meridian, though accurate as I had good reaſon to believe it to be, did not exactly

agree

agree in time with ſome Sun-dials and ſeveral Clocks, although thoſe Clocks were ſaid to be adjuſted by good Regulators: And when I endeavoured to find out the Variation of the Compaſs by the ſame meridian line, (which is the ſureſt way of diſcovering it accurately) it did not afford me the ſatisfaction which I had reaſon to expect; the Needle ſometimes pointing almoſt 30 degrees to the weſt of the north, though I had taken the utmoſt care in placing the Compaſs over the meridian line.—— But as I obſerved before, it was ſomewhat uncommon to ſee thoſe Needles, after being diſturbed, reſt twice together at the ſame point of the Compaſs. This was however a ſure proof that the fault was not altogether in the *Meridian Line*, which I was convinced muſt be an accurate one, as certainly as the Sun has equal Altitudes at equal times before and after it paſſes the true Meridian of the place.

79. But the caſe was quite otherwiſe when I placed my accurate Compaſs before-mentioned over my meridian line, as that gave the Variation about 20 degrees to the weſt of the Meridian at Worceſter, in the beginning of the Year 1766: Since therefore an Obſervation with an accurate Compaſs on a true meridian line gives about 20 degrees of weſt Variation, I ſhall ſhew what the Variation is by Calculation the ſame Year: And as it is a peculiar one, and ſerves to illuſtrate and ſtrengthen the Theory in general, I ſhall preſent my Reader with that Calculation at large.

In

80. The Longitude of London from the magnetic Meridian is found by calculation to be $104^\circ\ 31'\ 26''$ to the eaſt nearly; and the Longitude of Worceſter being about 2 degrees to the weſt of London; the eaſt Longitude therefore of Worceſter from the magnetic Meridian is $102^\circ\ 31'\ 26''$ the half of it is $51^\circ\ 15'\ 43''$.

In this Problem, the things given being the 2 ſides and the included $\angle$, I ſhall proceed as before by Mr. *Oughtred*'s proportion, which requires no perpendicular.

The Latitude of Worceſter $52^\circ\ 16'$
Complement $= 37^\circ\ 44' =$ one of the given ſides of the Triangle.
The Latitude of the magnetic Pole $76^\circ\ 9'$
The Complement $13^\circ\ 51' =$ the other comprehending ſide.

Their Sum is	$51^\circ\ 35'$
Their half Sum	$25^\circ\ 47'\ 30''$
Their Difference	$23^\circ\ 53'$
Their half Difference	$11^\circ\ 56'\ 30''$

As the s. of half the ſum of the 2 ſides $25^\circ\ 47'\ 30''$ Ar. Comp.	0.361411
to the s. of half their diff. $11^\circ\ 56'\ 30''$	9.315794
So is the ct. of half the contained $\angle$ $51^\circ\ 15'\ 43''$ — —	9.904491
to the tan of half the diff. of the other 2 $\angle$s $20^\circ\ 53'$ —	9.581696

And,

As

As the cs. of half the ſum of the given ſides 25° 47′ 30″ Ar.Com	0.045573
to the cs. of ½ their diff. 11° 56′ 30″	9.990494
So is the ct. of half the contained ∠ 51° 15′ 43″ — —	9.904491
to the tan. of half the ſum of the other 2 ∠s 41° 5′ 30″	9.940558

Add and ſubtract 20° 53′

61° 58′ 30″ = the greateſt ∠

20° 12′ 30 = the Variation of the Needle from the Meridian of Worceſter 1766.

81. I muſt own I was not a little elated at the remarkable agreement of my Obſervation and Calculation, ſimilar to a well correſponding Theory and Practice: In ſhort, I found ſo many concurring Circumſtances which ſeem'd ſo fully to confirm my Theory, that I had ſcarce a doubt remaining, ſince nothing of conſequence appear'd to contradict it. From this pleaſing Encouragement, I have, a little farther on, ventured to give the Variation of the Needle from the Meridian, at ſeveral capital Cities and Towns.

82. The Longitude of the *magnetical Pole* from London having been diſcover'd to be 180° that is, at the oppoſite part of the Meridian at *a*, about the year 1660; and as the yearly motion of it is diſcover'd to be 42′ 43″ 20‴, it has been conſequently ever ſince approaching towards

towards us at that rate, and muſt in 106 years be advanced 75 degrees at leaſt, and at this time cannot be much ſhort of the Meridian of *Acapulco* in *Mexico*; ſo that the Weſt Variation of the Needle at that Meridian is almoſt if not quite at an end, and an Eaſt one will ſoon begin.

83. Having therefore the yearly motion of the magnetic Pole we may eaſily find its place at all times, thus, From 180 degrees *viz.* the diſtance of the magnetic Pole from London, in 1660, if $42' \; 43'' \; 20'''$ be ſubtracted, there will remain $179° \; 17' \; 16'' \; 40''' =$ the Longitude for the Year 1661; then, if from $179° \; 17' \; 16'' \; 40'''$ be taken $42' \; 43'' \; 20'''$ the remainder is $178° \; 34' \; 33'' \; 20''' =$ the Longitude for the Year 1662; and thus we may proceed for every year till the magnetic Pole has paſſed through the weſtern part of its parallel ſtill ſubducting $42' \; 43'' \; 20'''$ till it arrives at the neareſt part of the Meridian where the Longitude would become $= 0$.

84. The following Series was formed by the ſame method of reaſoning for every other, that is, for every ſecond Year, by ſubtracting double the number of minutes, ſeconds, and thirds; ſo that if a particular Year be wanting that is not in the Table, add $42' \; 43'' \; 20'''$ to the next leſs, and thus the ſituation of the magnetic Pole may be known for any Year.

The

Table II. The *Longitude*, or *Distance of the magnetic Meridian* from that of London for every two Years.

Yrs.	Longitude. Deg.	m.	s.	3ds.	Yrs.	Longitude. Deg.	m.	s.	3ds
1660	180	00	00	00	1704	148	40	13	20
less	1	25	26	40	1706	147	14	46	40
					1708	145	49	20	0
1662	178	34	33	20	1710	144	23	53	20
less	1	25	26	40	1712	142	58	26	40
					1714	141	33	0	0
1664	177	9	6	40	1716	140	7	33	20
less	1	25	26	40	1718	138	42	6	40
					1720	137	16	40	0
1666	175	43	40	0	1722	135	51	13	20
&c.		&c.			1724	134	25	46	40
1668	174	18	13	20	1726	133	0	20	0
1670	172	52	46	40	1728	131	34	53	20
1672	171	27	20	0	1730	130	9	26	40
1674	170	1	53	20	1732	128	44	0	0
1676	168	36	26	40	1734	127	18	33	20
1678	167	11	0	0	1736	125	53	6	40
1680	165	45	33	20	1738	124	27	40	0
1682	164	20	6	40	1740	123	2	13	20
1684	162	54	40	0	1742	121	36	46	40
1686	161	29	13	20	1744	120	11	20	0
1688	160	3	46	40	1746	118	45	53	20
1690	158	38	20	0	1748	117	20	26	40
1692	157	12	53	20	1750	115	55	0	0
1694	155	47	26	40	1752	114	29	33	20
1696	154	22	0	0	1754	113	4	6	40
1698	152	56	33	20	1756	111	38	40	0
1700	151	31	6	40	1758	110	13	13	20
1702	150	5	40	0	1760	108	47	46	40

Yrs.	Longitude. Deg.	m.	ſ.	3ds	Yrs.	Longitude. Deg.	m.	ſ.	3ds.
1762	107	22	20	0	1830	58	57	4	20
1764	105	56	53	20	1832	57	31	37	40
1766	104	31	26	40	1834	56	6	11	0
1768	103	6	0	0	1836	54	40	44	20
1770	101	40	33	20	1838	53	15	17	40
1772	100	15	7	40	1840	51	49	51	0
1774	98	49	31	0	1842	50	24	24	20
1776	97	24	4	20	1844	48	58	57	40
1778	95	58	37	40	1846	47	33	31	0
1780	94	33	11	0	1848	46	8	4	20
1782	93	7	44	20	1850	44	42	37	40
1784	91	42	17	40	1852	43	17	11	0
1786	90	16	51	0	1854	41	51	44	20
1788	88	51	24	20	1856	40	26	17	40
1790	87	25	57	40	1858	39	0	51	0
1792	86	0	31	0	1860	37	35	24	20
1794	84	35	4	20	1862	36	9	57	40
1796	83	9	37	40	1864	34	44	31	0
1798	81	44	11	0	1866	33	19	4	20
1800	80	18	44	20	1868	31	53	37	40
1802	78	53	17	40	1870	30	28	11	0
1804	77	27	51	0	1872	29	2	44	20
1806	76	2	24	20	1874	27	37	17	40
1808	74	36	57	40	1876	26	11	51	0
1810	73	11	31	0	1878	24	46	24	20
1812	71	46	4	20	1880	23	20	57	40
1814	70	20	37	40	1882	21	55	31	0
1816	68	55	11	0	1884	20	30	4	20
1818	67	29	44	20	1886	19	4	37	40
1820	66	4	17	40	1888	17	39	11	0
1822	64	38	51	0	1890	16	13	44	20
1824	63	13	24	20	1892	14	48	17	40
1826	61	47	57	40	1894	13	22	51	0
1828	60	22	31	0	1896	11	57	24	20

Yrs.	Longitude. Deg. m. ſ. 3ds	Yrs.	Longitude. Deg. m. ſ. 3ds
1898	10 31 57 40	1906	4 49 11 0
1900	9 6 31 0	1908	3 23 44 20
1902	7 40 4 20	1910	1 58 17 40
1904	6 14 37 40	1912	0 32 51 0

85. Here it may be proper to remark again, that the things which give me the greateſt reaſon to believe that my firſt Principles are well founded are more particularly the three following:

Firſt. That the magnetic Pole or *Cauſe* of the change of the Variation, moves gradually: This appears from the gradual change of the Variation for near two hundred Years paſt, namely, from 1580 to the preſent time 1766; ſince this is entirely conſentaneous with the effects produced from ſuch a motion of the magnetic Pole round the Pole of the Equator, as the Theory affirms. Pl. IV. fig. 3.

Secondly. The exact agreement which appear'd between the Obſervations of the beforementioned learned Profeſſors Dr. *Halley*, and Dr. *Bradley*; the former of which in 1672 found the Variation about 2° 30′ to the Weſt, and the latter in 1750 found it 17° 25′. Theſe two Obſervations of thoſe great Men, coinciding ſo exactly, as they did, with Calculation, both in regard to each other, and the time when they commenced, that is, at the Year 1660: Theſe were, I think, ſuch ſtrong Circumſtances as might even biaſs a learned Man, eſpecially ſince,

 Thirdly.

Thirdly. They are farther confirmed by my Obfervation of the Variation at the City of Worcefter this prefent Year 1766, when as before obferved, an accurate Compafs being placed over a juft Meridian Line, points out the very place obtained by Calculation. Are not fuch hints fufficient to render the Theory worthy of an impartial Examination?

86. The only proper way of examining it, muft be, as before remarked, by parallel Sailing; there is Sea-room fufficient between *Ireland* and *America*, and in the parallel of London too*; and to prove more effectually whether the feveral Longitudes and the Variations agree according to what are exhibited in the Table. (See *Sect*. 50 and 55.) It might be neceffary to take one of Mr. *Harrifon*'s Clocks, that fo the true Longitude may be ready at hand to compare with the feveral Variations. It is alfo abfolutely neceffary that the Needle of

* The reafon I recommend parallel Sailing, is from a hint which occurred from Dr. *Halley*'s unfurmountable Difficulties; who after mentioning the wonderful length of a periodical Revolution of the magnetic Pole, concludes; *fo that the nice determination of this, and of feveral other particulars in the magnetic Syftem, is referv'd for later Pofterity*. —— All the Obfervations that could be made in London in 505 Years, might be very foon made by failing in the parallel H, G, K. C Fig. 2d. Plate IV. And diftance of *Place* in the latter, would be equal to diftance of *Time* in the former.

the

the Compaſs be good.——Unleſs ſuch a careful method be obſerved, the Theory, though ever ſo true, muſt appear defective, when compared with Practice; ſince it depends altogether on the accuracy of the Latitude and Variation, that is, on gaining both the Latitude of the place of Obſervation, and alſo the points of the Compaſs; for then, and not till then, can the Longitude be aſcertained to a ſufficient degree of exactneſs; and nothing leſs than ſomewhat of this kind can be deemed a fair Examination.

87. Other concurring favourable Circumſtances may here alſo be enumerated, in order to ſtrengthen and confirm the Theory; as firſt, that Dr. *Halley* obſerves that the greateſt Variations are near the north and ſouth Poles of the Equator. Secondly. That where the Variations ſeem unalterable, as it were, for a very conſiderable time, it is to be underſtood of ſuch places as are near the Tangents or greateſt Variations; and both theſe Phænomena are render'd ſo obvious in my Scheme, as to appear evident at firſt ſight. See fig. 2d 3d. Pl. IV.

88. Another Circumſtance in favour of this Theory is, that *Paris* has in reality leſs Weſt Variation than *London*; whereas Dr. *Halley* affirms *that according to the general effect, the difference ought to be the contrary way.*——Many other collateral Proofs might be mentioned, but thoſe already ſpecified muſt, it is imagined, be abundantly ſufficient to recom-

mend

mend the prefent Theory to a juft and proper Scrutiny: So that the unprejudiced Reader will not perhaps call me downright Fool-hardy, even though I have adventured to place the magnetic Pole in a Meridian near to that which runs through *Acapulco* in *Mexico*. —— He may probably act fo generoufly and favourably as to confider, that few Theories are brought to perfection at once, and therefore no wonder if it fhould happen fo in this cafe. Could I but expect fuch candid treatment, I fhould advance fomewhat farther and prefent the Reader with the Variation at many other Places, befides thofe of *London*, *Paris* and *Worcefter*.

89. Here it is to be noted, that in different Books of Geography, we have the Longitude of different places given very differently from each other and from different Maps, and fometimes the Latitudes alfo; and if thofe are incorrect, the Variation muft neceffarily come out wrong by Calculation. However relying on the Candour and Courtefy of my Reader, and not doubting but the novelty of the fubject will recommend it to his notice, I fhall give him a Specimen of what the Variations would certainly be at each place, exclufive of fuch miftakes.

90. I fhall begin with the Metropolis, or which is nearly the fame, the Royal Obfervatory at *Greenwich*.

To find the Variation at the Royal Observatory at *Greenwich* for the Year 1766. The difference of Meridians between the Observatory and the magnetic Pole being that Year 104° 31′ 26″.

I shall proceed as before by Mr. *Oughtred's* Proportion.

The Complement of the Latitude of that place 38° 31′ 30″

The Comp. of the magnetic Pole 13° 51′

Sum of the sides 52° 22′ 30″

Half Sum 26° 11′ 15″

Difference of the sides 24° 40′ 30″

Half Difference 12° 20′ 15″

Half the Angle 52° 15′ 30″

As s. of half the sum of the 2 sides 26° 11′ 15″ Ar. Comp.	0.355256
to s. of half their diff. 12° 20′ 15″	9.329743
So is the ct. of half the contained ∠ 52° 15′ 30″ — —	9.888785
to the tan. of half the diff. of the other 2 ∠s 20° 32′ 30″ —	9.573784

And,

As

As co-s. of half the sum of the 2 sides, 126° 11′ 15″ Ar. Comp. } 0.647667

to co-s. of half the diff. 12° 20′ 15″ 9.989839

So is the ct. of half the contained ∠ 52° 15′ 30″ — — } 9.888785

to the tan. of half the sum of the other 2 ∠s 40° 7′ } 9.925691

60° 39′ 30″ = the greatest ∠.

19° 34′ 30″ = the Variation at the Royal Observatory, 1766.

91. According to the same manner of reasoning, the West Variation at *London* for the present Year 1766 will be 19° 35′. That of *Paris* less by about a degree *.—If no material

* That the West Variation is not so great at Paris as at London appears by the 1st Table page 478, or by the 2d or 3d fig. Plate IV. where we find that the nearer the magnetic Pole approaches towards us, the more this Variation increases, i. e. the less the distance is, the greater is the Variation; consequently *Paris*, being farther to the East of it than *London*, must have less Variation. But here it is to be remember'd that this Phænomenon will be at an End after the magnetic Pole has reach'd the Tangent C v, or rather C p; because, after that, the Variation will decrease at London, and the less the distance is, the less will be the Variation; consequently Paris, which is at a greater distance than London, will then have the greater Variation, i. e. just the reverse of what it was before it came to the Tangent.

Error

Error hath happened in the given Longitudes or Latitudes of the several Places, the Variation at *Edinburgh* for the present Year 1766 is expected to be nearly 21° 56′.— At *Amsterdam* 19° 3′.— At *Madrid* 17° 5′.—— At *Lisbon* 17° 11′—— At *Rome* 14° 54′.—— At *Vienna* 15° 33′.—— At *Venice* 15° 38′ 30″.—— At *Naples* 14° 25′ —— At *Port-Royal* in *Jamaica* 7° 47′.—— At *Acapulco* in *Mexico*, very little.

In the Meridian of *London* at the Arctic Circle the Variation for the present Year is 27° 40′.

C H A P. VI.

SECTION 92.

Of the greatest Variations *that can happen at* different Parallels of Latitude.

THE greatest Variation at the Equator is equal to the distance of the magnetic Pole from the Pole of the Equator, since both of them are at that time in the Horizon of the place of Observation, *viz*. 13° 51′.

In the Parallel of *Port-Royal* = 17° 30′ of North Latitude, the greatest Variation is 14° 32′ and is obtained by the first Case of right spherical Triangles Thus,

As the Sine of the Complement of the Latitude of the Place of the Observer, to Radius; so

ſo is the Sine of the Complement of the Lat. of the magnetic Pole to the greateſt Variation. See Pl. IV. fig. 4. where there is given the Side CP and the Side *m*P to find the ∠ *m*CP.

As s. CP	75° 28′	— —	9.979419
to Rad.			10.
So is s. of *m*P	13° 51′	—	9.379089
to s.	14° 32′		9.399670

In the Parallel of Latitude 30°, the greateſt Variation that can happen is 16° 3′.

In the par. of 40° the greateſt is 18° 12′ 30″.

In 50° —— 21° 52′.

In 60° —— 28° 36′ 30″.

In 70° —— 44° 25′.

In 74° 24′ —— 62° 53′, or full North-weſt.

In the Parallel of 76° the greateſt Variation is 81° 41′ 20″.

N. B. Were we to ſail to thoſe northern Limits beyond Latitude 76° 9′, the greateſt Variation would be 180°, that is, the magnetic Pole is ſometimes to the ſouth of thoſe parts, and conſequently the Needle ſometimes points to the ſouth inſtead of the north; ſo that unleſs a *Theory of the magnetic Pole and Variation of the Needle be obtained*, as that Pole is approaching towards our Meridian, it will be in a few Years ſo near to us in thoſe limits that the Variation will change ſo ſenſibly at every different ſituation of the Ship, that the Needle will be but of little ſervice to the Navigator.

93. In order to confirm the foregoing positions I have only to requeſt, I will not ſay *require* of my Readers, that they will grant me that fair, reaſonable Poſtulatum, which Nature herſelf moſt evidently points out to us, *viz.* that the magnetic Pole moves in a circular Orbit round the Pole of the Equator *, and that the Mariner's Needle, if perfectly good, is conſtantly directed towards it, as it appears to be, in fact; and then the finding of the Longitude by this method will amount to a compleat demonſtration, and to be founded on true, ſure, and laſting Principles.

94. Table III. This Table is conſtructed on the ſame principles as the 1ſt (*See Sect.* 50.) for the Parallel of *Port-Royal in Jamaica*, Lat. 17° 30′ Lon. 74° 0′. Each Calculation differing from the other 15 degrees of Longitude, beginning at the Meridian of *London*.

Alſo for the *Arctic Circle*, Lat. 66 31′; the Calculations differing from each other 10 degrees of Longitude. To find the ſeveral Variations.

* Since all the Phænomena are conſentaneous and agreeable thereto.

Arctic Circle.

Yrs.	Longit. D.	m.	Variation. D.	m.	
1660	180	0	0	0.	
1674	170	0	3	56	
1688	160	0	7	51	
1702	150	0	11	42	
1716	140	0	15	30	
1730	130	0	19	10	
1744	120	0	22	39	
1758	110	0	25	37	
1772	100	0	27	35	
1786	90	0	31	45	
1800	80	0	34	3	
1814	70	0	35	42	
1828	60	0	36	45	
	56	0	36	55	
1842	50	0	36	43	
1856	40	0	35	8	
1870	30	0	31	18	
1884	20	0	24	23	
1898	10	0	13	41	
1912	5	0	7	4	
	4	0	5	41	
	3	0	4	16	
	2	0	2	52	
	1	0	1	26	30
	0	0	0	0	

Port-Royal in Jamaica.

Yrs.	Longit. D.	m.	Variations D.	m.	
1660	180	0	0	0	
1681	165	0	3	34	
1702	150	0	6	55	
1723	135	0	9	50	
1744	120	0	12	10	
1765	105	0	13	46	
1786	90	0	14	29	
1807	75	0	14	11	
1828	60	0	13	7	
1849	45	0	9	50	
1870	30	0	7	53	
1891	15	0	4	8	30
1912	0	0	0	0	

It may be thought neceſſary to remark, that the above Calculations might have been made more exact in Time by inſerting the fractional parts; but as the whole did not amount to one Year, I purpoſely omitted them.

CHAP.

CHAP. VII.

SECTION 95.

Modern Geography, *or* Geography *improved by means of the* magnetic Theory.

HAVING proceeded thus far with my Theory of the *magnetic Pole* and *Compafs-needle*, a kind of new Geography appears; for having obtained the Longitude or diftance of the magnetic Meridian by the foregoing method, a Queftion may be put, *viz.* though the Longitude of the Meridian poffeffed by the magnetic Pole be known; yet how can the Mariner obtain his diftance from any known place nearer to him, as *London, Teneriff, Ferro, &c?* I anfwer: By a method fimilar to that made ufe of in common Geography: For as in that, a firft Meridian is found neceffary; fo the fame is as neceffary here: But as in *that*, the Meridian of fome known place was made the firft Meridian; in *this*, the Meridian poffeffed by the magnetic Pole muft be deem'd the firft Meridian: The principal difference is, in that, the Place and its Meridian is fixed; in this, it is perpetually fhifting from one Meridian to another; but that makes no difficulty, fince its

place

place or Longitude may be known for any particular Year, from Table II. by which means we have a general or first Meridian, equally capable of affording all the assistance as that of *Teneriff, &c.* Or, if we please, one of those forementioned places which was called the first Meridian, may now be called a second Meridian, with which we may proceed in a similar manner to that in common use.

96. If the Longitude of *London* from the magnetic Pole be required for any given Year, suppose the present Year 1766: Look into Table II. for that Year, opposite to which will be found the Longitude or distance of the magnetic Meridian from that of London, 104° 31′ 26″ 40‴*: The same for any future Time.

Second. As in common Geography, so also here the distance from the first Meridian being known, if their distance from each other be required, the Problem admits of *three* different Cases: *First*, if the Places are both to the East or both to the West of that first or grand Meridian, subtract the least distance from the greatest and the difference is the desired distance of the places. *Second.* If one has East Longitude of *that Meridian*, and the other West, add them together, and their sum is the distance of the places. *Thirdly.* If the Needle has no Variation from the Meridian, there will then

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* The *Seconds* and *Thirds* in the Table may be disregarded in common use.

con-

consequently be no Longitude or distance from it.

N. B. It is to be remember'd that the Navigator having the Latitude and the Angle of Variation, has always *data* sufficient to discover his Longitude, or distance of the magnetic Meridian, since the side of the Triangle P*m*, *viz.* the distance of the magnetic Pole from the Pole of the Equator is permanent, and therefore always known.

Examples of the *three* different *Cases.*

97. Example I. Case I. Suppose in the *Atlantic* Ocean, the distance or Longitude from the magnetic Pole be found 62° 30′ to the east of it, then since London is also to the east, subtract 62° 30′ from 104° 31′ and the difference *viz.* 42° 1′ is the distance of the Meridian of the Observer to the west of London.

Example II. *Case* I. Suppose the Navigator to be in the *Mediterranean*, and his distance from the magnetic Meridian be 123° 30′ to the east, subtract 104° 31′ from 123° 30′ and the difference 18° 59′ is the distance of the Meridian of the Observer from that of London, and so much he would be to the east of it.

Example. Case II. Suppose, in the great south Sea, the *Manila Ship* from Acapulco finds her Longitude or distance from the magnetic Meridian to be 33° 45′ to the west, if 33° 45′ be added to 104° 31′ it shews the difference of Meridians to be 138° 16′, and so far that place would be to the west of London.

Ex-

Example. Case III. If the Needle have no Variation from the Meridian, the Mariner may then conclude himself to be *at* the magnetical Meridian, and consequently that he is 104° 31′ to the west of London, *viz.* the number of degrees found in the Table at the Year 1766.

98. Having found the Longitude or distance of the magnetic Meridian in degrees, multiply it by 60, and that will give the distance in Miles.

Example. For London 1766.

Having found the Variation 19° 35′ say by *Case* II. of oblique-angled spherical Triangles.

As the s. of the ∠ of Variation 19° 35′	Arith. Comp.	0.474725
to s. of the side *m*P	13° 51′	9.379089
So is the s. of the ∠ CP*m* 104° 31′ whose Comp. to 180 is	75° 29′	9.985909
to s. of the side *m*C	43° 44′	9.839723
which multiplied by 60		
gives the dist. in Miles 2624*		

* As in common Geography, great Circles of the Sphere multiplied by 60 give Miles, and as all right Lines in spherical Projections, passing thro' the Center, are great Circles: Consequently the right Line C *m*, in the Projection by passing thro' the Center is a great Circle, and therefore if the degrees are multiplied by 60, they are converted into Miles here also.

99. The diſtance of the magnetic Pole from that of the Equator, made uſe of in the foregoing Calculations was obtained by Mr. *Hauxley* *, which diſtance appears to be right; ſince every Calculation in which it was concerned, that I have had an opportunity of proving by Obſervation came out either accurately juſt, or elſe exceedingly near.

100. But whether his diſtance of the *two* Poles = 13° 51′ was accurate or not, I ſhall now, according to a former promiſe, exhibit a ſimple, eaſy, and infallible method to ſhew: By the 18th Propoſition of the 3d Book of Euclid it is demonſtrated, that if a line be drawn from the center of a Circle to the tangent thoſe two lines will form a right angle. Now at the time of the greateſt Variation at London or elſewhere, ſuch a rectangled Triangle is formed, as C*p*P, Pl. IV. fig. 2, right angled at *p*, where there is given the ſide CP = the complement of the Latitude of the place, and the ∠ of Variation PC*p*, to find the diſtance P*m*.

101. If it be ſtill objected, that though I have ſhewn an infallible method to find the diſtance of the magnetic Pole from the Pole of the Equator; yet in another caſe my Plan ſeems to be defective, *viz.* in the Time of the periodical Revolution, which Dr. *Halley* makes to be about 700 Years; and that I myſelf have alſo acknowledged that the Time of the peri-

* See *Gentleman's Magazine* for *May*, 1750.

odical Revolution, founded on the Obſervations of Dr. *Halley* and Dr. *Bradley*, (when the Variation was to the Weſt of the Meridian) does not coincide with the Obſervations of *Burrows*, *Bond*, &c. whilſt the Variation was to the Eaſt.

I anſwer: Though I have acknowledged that according to their Obſervations it ſeemed to be ſo, yet if that were really the Caſe, i. e. if that Pole did actually move ſometimes faſter and ſometimes ſlower, yet I do aver, that were it even *fixed* in any part of its parallel, it would not affect the Truth of my Theory at all. The finding the Longitude at Sea would be entirely the ſame in every reſpect; for ſo long as the Index or Needle points it out, there will ſtill be ſuch a Triangle formed, as will afford equal Data to find the Longitude, i. e. the angle PC*m*. For inſtance; ſuppoſe it fixed at *m*, ſee Pl. IV. fig. 3. though the Variation, and conſequently the Triangle would be the ſame at the Royal Obſervatory; yet, as the Navigator changes his ſituation, his angle of Variation and conſequently his Triangles would be different, juſt, or nearly in the manner it is at preſent, which is the ſame, allowing only for the few minutes it moves in a whole Year.

N. B. The difference which appears between the motion of the magnetic Pole when toward the eaſt of London and when it was to the weſt, can ariſe from no other probable Cauſes than the faultineſs of the Needles and inaccuracy of the Obſervations, whilſt the magnetic

netic Pole was in the eaſtern part of its parallel, unleſs ſome ſmall degree of error may be aſcribed to the Obſervations of thoſe two great Men. It is ſufficient however, that their Obſervations were ſuch as have enabled me to begin a Theory, which if attended to, and carried on to thoſe Improvements of which it is capable, will aſcertain the Longitude to as great an exactneſs, as the well-known Latitude and Variation. So that whether the weſt Variation be quite at an end at *Acapulco*, or whether an eaſt one be juſt begun, it does not in the leaſt prevent the principal thing from ſucceeding, *viz.* that of finding the Longitude infallibly by this method.

102. That there is, near the ſouth Pole, another magnetic Pole, ſimilar to that near the north Pole of the Equator; and that they both probably have a connection with each other in their ſeveral Offices, may reaſonably be inferred from the Order, Beauty, and Harmony, conſpicuous throughout all the Works of Nature.

103. There cannot, however, be much doubt, when once a ſatisfactory *Theory* of the north magnetic Pole and Compaſs-needle is compleated and ſettled, but that *another* of the ſouth, founded on the ſame ſound Principles, will ſoon follow; and how bleſt will the Mariner then be, when he is poſſeſſed of ſo eaſy and ſimple a method to diſcover his Longitude in every Part of the terraqueous Globe? He will then require no more Data to proceed

with than thoſe that are juſt neceſſary to enable him to ſail at all, *viz.* his Latitude and angle of Variation: For as to the other requiſite, namely, the diſtance of the *two* Poles, that being once found is permanent, and therefore always ready at hand.

104. After I had proceeded thus far, a particular Friend obſerving me to be rather confident in my Aſſertions, remarked, with ſome Rallery, that though what I ſo ſtrenuouſly inſiſted on appeared true and undeniable to him, as well as to me; yet it was his opinion I ſhould be cenſured by ſome for affirming a Thing to be abſolutely true in fact, which I advanced only as a Theory; and that a method of finding a matter of ſuch Importance as the Longitude at Sea ought not to be admitted as certain, till it had paſt the teſt of a ſevere Trial, and been carried into actual execution. This Reaſoning appeared ſomewhat plauſible; and ſuch a Trial is what I have hoped for, and do ſtill earneſtly wiſh and deſire: For as I ſhould be very unwilling to be impoſed upon myſelf, ſo neither would I wilfully impoſe or intrude any falſe Reaſoning upon others: I ſhould therefore think myſelf very happy to have my Theory ſtrictly, impartially, and expeditiouſly examined, which cannot be effectually done, but by parallel ſailing, as I before obſerved, and without which, I can never expect to ſee it reduced to Practice.

105. To ſhew therefore the ſincerity of my

Intention, I have now ventured farther than my original Deſign, in calculating the Variation for every 10th degree, quite acroſs the *Atlantic* Ocean, as far as 80 degrees weſt Longitude from, and in the parallel of *London*. —— But as the *Navigator* will be prevented from ſailing farther in that parallel than 52 degrees of weſt Longitude, or thereabouts, by the north-eaſt coaſt of *Newfoundland*, I have taken the liberty of intruding a calculation for that particular Longitude.

106. In order to which, I ſhall farther ſuppoſe the Latitude and Variation juſtly obtained at 10 degrees to the weſt of London and in the ſame parallel; then unleſs I have incurred ſome material Error, (which not unfrequently happens to Perſons of much ſuperior Talents,) by the Calculations for the preſent Year 1766, the Variation is expected to be, at 10 degrees of weſt Longitude from London, about 21° 5′.— At 20 degrees from London 22° 6′ 45″.—— At 30 degrees 22° 36′ *.—— At 40 degrees

* The greateſt Variation.

If any Mariner, making a particular and accurate Obſervation in the above Longitude and Parallel, in 1766, ſhould find this to be nearly true, the diſtance between the magnetic Pole and the Pole of the Equator might be eaſily and infallibly obtained, (which muſt be nearly 13° 51′) and would confirm this Theory beyond a doubt, ſince almoſt all Calculations, which I have proved, have anſwer'd to a ſurpriſing exactneſs.

22*

22° 25′ 30″.——At 50 degrees 21° 29′——Now if the Longitude from London be 52° 16′ at the north eaſt coaſt of *Newfoundland*, the Variation will be 21° 8′ 39″. Here the Navigator can proceed no farther to the weſt in the ſame parallel, if our Maps are juſt.——At 60 degrees, the Variation is 19° 35′.——At 70 degrees 16° 47′ 40″.——At 80 degrees 13° 54′.——And at 104° 31′ 26″, the Variation of the Needle would be = 0.

107. To aſcertain this the more clearly, the uſe of Mr. *Harriſon*'s Clock will be expedient, that ſo each Obſervation may be made preciſely at 10, 20, 30, *&c.* degrees from London; for otherwiſe (as the Variation is conſtantly varying throughout the whole Voyage) it cannot be deem'd a fair Trial.

108. To conclude: The Diſcovery of the Longitude by the Variation of the Needle has been attempted upon very different Principles.

109. The great Dr. *Halley*, to correct the Longitude by the Variation, deſcribed curved Lines, which comprehended large Tracts of the ſurface of the Globe; each part contain'd within thoſe limits had the ſame degree of Variation, which does not ſuppoſe that the Compaſs-needle pointed to any particular Agent or Pole.

110. Meſſrs. *Mountaine* and *Dodſon* thought to improve the Drs. Plan by inſerting a great number of thoſe curved Lines on a very large paſteboard Chart; which lines, tho' they interſect or croſs

obliquely

obliquely a vast variety of different Meridians; yet are all marked as having the same Variation from one end to the other, the most remarkable of which is the Line of 20 degrees of west Variation, which is continued for 60 degrees of Longitude, almost due east and west, viz. from Great Britain to New England. By their Title Page, these Observations were made about 1756; and tho' the westerly Variation has been ever since increasing, it is not even *yet* full 20 degrees at London.

111. The present Theory is founded upon a persuasion, that the Needle, like an accurate Index, constantly points towards the magnetic Pole, and is the Cause of the Variation of the Mariner's Compass-needle, and of the Variation of that Variation.

112. If that Theory, which supposes the Needle points to nothing, is true, and can be proved, the present Theory must be false; and I will own myself mistaken. We may then attribute the Variation, with other *immechanicals*, to the immediate Influence and Interposition of the Deity; and tho' we can move the Needle with a piece of common Iron which way we please, yet we must not allow that the Needle is in the least affected by the Iron, but by some immaterial and intelligent Being; and that the assistance, which the Navigators receive from it, is all *immechanical* too.

113. Thus have I presented the Public with my Sentiments on the Longitude, together with the arguments and calculations upon which they are founded, I shall only observe farther, that the magnetic Pole, that Wonder of Nature, plainly exhibits the strongest marks and indications of its important Use, *viz.* that of enabling the Mariner securely to traverse the wide and pathless Ocean, to convey himself to the remotest

Re-

Regions, and to encounter the moſt turbulent Winds and mountainous Waves under the ſafe direction of his Compaſs-needle, which ever carefully, and as it were, dutifully watches the motions of its ſubterraneous maſter, and (if there be no fault in its Conſtruction) points them out, for the Benefit of Mankind, to ſo great a degree of accuracy and exactneſs, as to have occaſioned the poetical Proverb, "*True as the* Needle *to the* Pole." And unleſs this Truth, which ſtands confirmed by conſtant experience, can be diſproved and ſet aſide, my former Aſſertion muſt remain irrefutable. And if this Method ſhall on a ſtrict examination, be found capable of diſcovering the Longitude fully and permanently; is it not reaſonable to hope and expect that a proportionable part of the Premium ſettled by *Parliament* will be allotted to it, eſpecially if no other method be equally practicable and uſeful?

114 Having treſpaſſed, I fear, too long on the Patience of my Readers, I will now cloſe the whole with a Repetition of that Requeſt, with which I thought it my Duty to addreſs them at firſt; humbly craving their candid Allowances in favour of a diligent but *unletter'd* Labourer in the Fields of Philoſophy, to the better cultivation of which, if the preſent Publication ſhall (in the leaſt degree) contribute, I ſhall think myſelf happy in my Endeavours and Studies.

FINIS.

POSTSCRIPT.

On the Conſtruction of electrical Machines.

SECTION. 115.

OF theſe there are various forms, to be had of the mathematical Inſtrument-makers, ſome of which are very elegantly finiſhed.

116. A plainer and cheaper Sort are made and ſold by Mr. *Read*, *Cabinet-maker*, at the Quadrant, in *Knights-Bridge*, Hyde-Park. Theſe, by means of a ſimple contrivance, act the ſtrongeſt of any I have ever ſeen *.

117. The ingenious Mr. *Lane*, Apothecary, in *Alderſgate-ſtreet*, has one of them, which, with the greateſt eaſe, ſtrikes a hole quite through a quire of Writing-paper: He has alſo much improved it with an Electrometer, by means of which, he can regulate the force of it to any degree leſs than the greateſt force of the Machine in any kind of weather; and although it act ever ſo ſtrong, by ſuch a regulation he can make it as weak as you pleaſe.—— The Electrometer or Regulator may be had along with the other part of the Apparatus, if beſpoke, otherwiſe not.

118. Another of a yet more ſimple form is mentioned by Dr. *Franklin*, at p. 17 of his Letters. I once ſaw one of this kind that acted exceeding well, and for the ſimplicity both of that and its Apparatus, I have exhibited a figure of it; ſo that almoſt any one that ſees it may be able to form one of the

* The conſtruction of Mr. *Read*'s Machine is very ſimple and a Perſon on occaſion may perform Experiments on himſelf, without an Aſſiſtant.

ſame. Let AB Pl. II. fig. 3. be the glaſs ſpheroid, PHLK the Frame of the Machine, HGKM a large tin Cann filled with water; the glaſs Receiver may be either of a conical or cylindrical form filled with water as high as that in the Cann, and immerged into it.

119. When the Tyro is deſirous to try the force of this ſimple Machine, (when in motion,) he muſt communicate, by means of a Chain or otherwiſe, with the tin veſſel which contains the water, and then with the hand at liberty, or a wire, *&c.* touch the prime Conductor IK.

120. But that no one may be at a loſs for a Receiver properly prepared, let a Phial or a thin glaſs veſſel of any form be filled within an inch or an inch and an half of the top, and then immerged in water to the ſame height with the water in the glaſs; this will prove an exceeding good one, eſpecially if the water be made a little warm. Make uſe of it thus:

121. Set the veſſel of water with the phial, under any part of the excited Apparatus, as the prime Conductor or any of the electriſed wires, and let a wire or chain hang down from the Conductor *&c.* ſo that the lower end may deſcend into the water in the phial, and it will very ſoon be ſufficiently charged, as will be found by firſt taking a wire or rod of iron in one hand and putting the other end of it into the water in which the phial is immerged; then if a finger of his other hand or a rod of metal be brought to any part of the excited Apparatus, he will be convulſed as uſual: If the immerged glaſs be very thin and very large, the ſhock will be in the ſame proportion: If the veſſel of water in which the water is immerged be a long trough, and the glaſs be put at one end of it and the wire *&c.* to the other, the ſhock will be propagated in the ſame man-

manner as if brought ever ſo near to the immerged glaſs. Or,

122. Laſtly, if the glaſs be immerged to the ſame depth in the water at the ſide of a Pool or of a River, the ſame effect will happen, though the metallic rod be put into the water at the greateſt diſtance from it, if the Apparatus of wires be continued from the revolving glaſs till it comes ſo near to the Perſon that he may bring the rod in his other hand *to* it.

N. B. A worthy Friend, who is a *Gentleman* of the Faculty, in a neighbouring *County*, ſent me the following Letter.

123. "I have had, and ſtill have, very great practice in the electrical way, and as great Succeſs. Several remarkable Caſes I have ſent to the *Magazine* Compilers, but could never ſee one inſerted; tho' at the ſame time, I have ſent poetical pieces, which have been immediately publiſhed. Being therefore determined to trouble myſelf no more about them, muſt beg you, if ever you publiſh again, to inſert the following Caſe.

Richard Johnſon, *of the* Trench, *near* Wellington, *was laſt Winter attacked with an univerſal Rheumatiſm, which, with the ſymptomatic Fever which ran very high, confined him more than two months, notwithſtanding all proper means were made uſe of that might contribute to his Recovery. With the returning Spring, his pains vaniſhed ſucceſſively, all but a continual one in the Occiput and Vertebra of the Neck: Uſe was made of a fleſh Bruſh, James's Powder was repeatedly adminiſtred, a Bliſter was applied upon the part; but it baffled all our endeavours and continued obſtinate without the leaſt remiſſion, till* Electricity *was made uſe of in the latter end*

of May or the beginning of June, I forget exactly which; he persisted in the use of it about 10 *days: The first three or four days I began to despair of the Case, as he found not the least relief; but after that it began to abate, and at last entirely ceased.*

I could give you Cases enough to fill a Volume; but the above Case, though perhaps not so striking to the ignorant Reader as some I could relate, is in my opinion as wonderful a Cure as ever was performed; for being under my Observation from the beginning, I am satisfied nothing was omitted which could have been tried with any probability of success; and that the situation of his Complaint was primarily in the spinal Marrow. An ingenious *Clergyman* in the neighbourhood has done a great deal of good with his Machine; and the Practitioners at *Salop Infirmary* have at last got a succesful Method of using it."

124. The learned Professor *Boerhaave*, while reasoning with his Pupils concerning the effects of Fire, has the following *Corollary*, "What now is the greatest degree of Fire that human skill and industry can at present produce? Why, from what has been laid down, it plainly appears, that it would be in that place where the *Focus* of *Vilette*, and the strongest of *Tschirnhausen* should be made to meet together in an opposite direction, and coincide. For since the *Focus* of the *Speculum* is in the open Air, and in a point of its *Axis* three feet and an half distant from its *Vertex*; hence, this *Apparatus* of *Tschirnhausen* may be so placed between the *Speculum* and the Sun, in the *Axis* of both of them, that this dioptrical *Focus* shall exactly unite with the former catoptrical one, and that without at all preventing the Solar Rays from falling upon the *Speculum*. In this place of concourse then will be found the most intense

tenſe Fire, that human art at preſent is capable of exciting". *Boerhaave*'s Chemiſtry, p. 151. *See* Pl. III. fig. 2. and 3. Where the foregoing Experiment is thus delineated: MR repreſents *Vilette*'s Mirror, MPR the *Cone* of reflected Rays. ——— LN *Tſchirnhauſen*'s glaſs Lens, LPN the *Cone* of refracted Rays, and the *Focus* of each meeting at the common *Vertex*.

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TO THE

FIRST PART.

N. B. The Figures refer to the Sections.

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APPENDIX.

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A
GLOSSARY;
OR,
An EXPLANATION *of*
The moſt difficult Words in this Book.

A

ABRADE, *to ſhave, or pare off.*
Abſtruſe, *obſcure, not eaſy to be underſtood.*
Accelerate, *to haſten or quicken, to increaſe the motion of a thing.*
Acid, *tart, ſharp.*
Accumulate, *to heap up.*
Adequate, *equal, proportional.*
Æther, *a more pure and perfect air than that of the atmoſphere.*
Æthereal Fluid, or Medium, *the ſubtile medium diſcovered by the electrical apparatus.*
Agent, *a being endued with the power of action.*
Aggregate, *the whole ſum or maſs that ariſes from the gathering together or compounding of ſeveral things.*
Agitate, *to move, ſtir up, excite.*
Air, *is that fluid in which we move and breathe, and without which we cannot ſubſiſt.*
Alluſion, *a likening or applying one thing to another.*
Alternate, *whatever is done by turns, or one after another.*
Amalgama, *a paſte compounded of metals and quickſilver.*
Angle, *the meeting of any two lines which incline to one another in a certain point.*
Animate, *to enliven or quicken.*
Antagoniſt, *an oppoſer or adverſary.*
Apparatus, *a collection of inſtruments uſed to ſhew experiments, &c.*

Aquatic, *watery, or belonging to the water.*
Arcanum, *a ſecret.* [*figure.*
Area, *the ſuperficial content or meaſure of any body or*
Atmoſphere, *the lower part of the region of the air or Æther, with which our earth is ſurrounded, and into which the vapours,* &c. *are carried.*
Attraction, *a drawing of one thing to another.*
Attrition, *rubbing, wearing, or fretting.*
Augmentation, *increaſing, enlarging.*
Axiom, *a plain, ſelf evident truth or propoſition.*
Axis, *an imaginary line paſſing thro' the center of any figure or orbit* &c. *about which the revolution is perform'd.*

B.

Barometer, *a machine for meaſuring the weight of the atmoſphere, and the variations thereof.*
Baſis, *the bottom, foundation, or foot upon which any thing ſtands.*

C.

Calcined, *reduced to powder, by fire or corroſives.*
Camera obſcura, *an optical machine, for the exhibiting of the pictures of external objects in their proper colours.*
Capſula, *the caſe or huſk of any thing.*
Capillary tubes, *ſmall tubes or hollow pipes, not much larger than a hair, for the conveyance of liquor, light, or ſound.*
Catoptrics, *that branch of optics which delivers and demonſtrates the laws of light,* reflected *from mirrors, ſpeculums, and looking glaſſes &c.*
Cavity, *any hollow part or place.*
Cauſe, *the producer of an effect.*
Celeſtial, *of, or belonging to the heavens.*
Center, *a point equally remote from either of the extremities of a line, figure, or body.*
Center of Gravity, *that point about which all the parts*

of a body in any ſituation balance each other.

Centrifugal, *that endeavours to fly or go from the center or fixed place.*

Centripetal, *whatever forces, draws, inclines, or compels things toward their center.*

Chaos, *a confuſed jumble, heap, or mixture of things of differing natures.*

Circuit, *a circle, an ellipſis, or any other figure that begins and ends at the very ſame point.*

Coheſion, *the action whereby the conſtituent particles of natural bodies are connected or joined together.*

Circumambient, *any thing that flows round or encompaſſes ſome other thing; an epithet chiefly applied to air.*

Comet, *a blazing ſtar.*

Comminution, *the breaking, grinding, or reducing to very ſmall parts.*

Compaſs-needle, *that moſt uſeful inſtrument for mariners, by which they guide the courſe of their ſhip.*

Component, *that of which a body is compounded.*

Compreſſible, *that may be ſqueez'd, reduced, or brought into a narrower compaſs than it naturally occupies.*

Coagulate, *to congeal, curdle, or thicken.*

Coalition, *a growing together of parts ſo as to compoſe one common maſs.*

Colliſion, *a daſhing or ſtriking of one body againſt another.*

Combuſtible, *any thing that is proper to feed, and eaſy to take fire, as oil, pitch,* &c.

Concatenation, *a joining, tying, or linking things together.*

Concentric, *ſeveral circles of different areas, that are ſwept from one common center.*

Condenſity, *the bringing a body into leſs compaſs than it uſually takes up.*

Condenſing Phial, *the glaſs receiver or collector of the*

electrical fluid, by which its great force is exerted.

Cone, *a solid body, that has a circle for its basis, and is terminated in a point at the top called the vertex.*

Conical, *belonging or relating to a cone.*

Constituent, *an essential part that composes any thing.*

Contraction, *a drawing or closing together.*

Continuity, *the joining or connecting of the several parts of any thing.*

Converging, *those rays which go from divers points in the object, and incline towards one another till they meet in a point.*

Corollary, *a consequence or conclusion drawn or made from some antecedent demonstration.*

Corpuscles, *the smallest part or physical atoms of a body.*

Co-sine, *the sine of an arch, which is the complement of another to 90 degrees.*

Cosmographical, *relating to cosmography, or that science, which teaches the structure, form, disposition and relation of the parts of the whole world.*

Co-tangent, *is the tangent of any complemental arch, or what the arch wants of 90 degrees.*

Criterion, *the test or proof of the truth or falsehood of a thing.*

Cube, *a regular solid, with six square and equal faces, all at right angles with one another.*

Culinary, *belonging to a kitchin.*

Cupelling-test, *a furnace or frame composed of bone-ashes,* &c. *for refining metals,* &c.

Curve, *the periphery, or any part of a circle, ellipsis,* &c.

Cylinder, *a round solid having its bases circular, equal and parallel, as a rolling-stone.*

D

Data, *such things as are known, given or granted in a proposition.*

Dense, *thick, a philosophical term opposed to thin.*

Defi-

Desideratum, *something wanting, or sought for.*

Diameter, *is a line which passes through the center of a circle, and is bounded by the circumference on each side, dividing the circle into two equal parts.*

Dilatation, *a motion in the parts of a body, whereby it expands itself to a greater bulk than usual.*

Dimension, *the just measure or compass of any thing.*

Diminution, *diminishing or lessening, abating or decrease.*

Distillation, *is the extraction of the humid part of things by heat, which humid part is first resolved into vapour, and then condensed again by cold.*

E

Ecliptic, *the earth's annual orbit.*

Effluvia, *small particles of matter that fly off from bodies.*

Elasticity, *is a springiness which most bodies have more or less, a power to return to its first place and condition, as a stick which is forcibly bent; the air has it in a very remarkable manner, and being compressed, it endeavours, with a very great force, to restore itself to its former state.*

Electrical fluid or medium, *the medium discover'd by the electrical apparatus.*

Electricity, *is the property that amber, jet, glass, sealing wax,* &c. *have of attracting very light bodies to themselves when rubbed or chaffed.*

Electrometer, *an instrument wherewith to measure the force of electricity.*

Electrics per se, *those bodies in which the electrical fluid is fixed.*

Elementary, *belonging to elements.*

Elements, *the first principles or ingredients, whereof bodies are composed; and are conceived to be simple and homogeneous.*

Emanation, *flowing, darting, proceeding, or issuing out of, or from a thing.*

Ener-

Energy, *force, efficacy.*
Ens rationis, *whatever exiſts in the imagination only.*
Epi-cycle, *a little imaginary circle invented to ſolve the ſtations and retrogradations of the planets.*
Equilateral, *is a figure whoſe ſides are all equal.*
Equilibrium, *equality of weight and poiſe, equal balance.*
Eſſential, *the nature, ſubſtance, or being of a thing.*
Eſſential properties, *ſuch as neceſſarily depend on the nature or eſſence of any thing, and are inſeparable from it, in diſtinction from accidental or caſual.*
Exhalation, *a fume, ſteam, or vapour.*
Exhauſted, *drawn out, emptied.*
Exiſt, *to be, or have a being.*
Expanſion, *the ſwelling of a fluid by means of rarefaction.*
Expiration, *a breathing out.*
Exſuction, *drawing out by ſucking.*
Extenſion, *ſtretching out or enlarging.*
Exterior, *the outſide, or apparent part of a thing.*
External, *on the outſide, outward.*
Extremity, *the end, edge, or brink of a thing.*

F.

Fermentation, *an inteſtine motion of the ſmall inſenſible particles of a mixed body.*
Fiat, *let it be done; an authoritative ſpeaking things into being, — as, " let there be light "*
Fibres, *the threads or hair like ſtrings of muſcles, veins, plants, roots,* &c.
Filament, *See* Fibres.
Fire, *a moſt pure element ſubſiſting without a pabulum, and yielding neither ſmoke, aſhes, or any other groſs matter.*
Firmament, *the viſible and apparent expanſe or arched covering over us.*
Fluid, *readily, or eaſily flowing, like water.*

Fluxion,

Fluxion, *a flowing or running by heat or fire.*

Factitious, *artificial, counterfeit, endeavouring to resemble nature.*

Focus, *the point of convergence, or concourse, where the rays meet and crofs the axis, after their refraction by the glafs.*

Force of gravity, *that quality by which bodies tend to the center of the earth, or to each other.*

Foffils, *all bodies that are dug out of the earth.*

Friction, *rubbing, or chaffing.*

G.

Generated, *begotten, or produced.*

Genial, *that which contributes to propagation.*

Genus, *the ftock, or general name comprehending the fpecies under it.*

Geometry, *the fcience of quantity, extent, and magnitude.*

Gravity, *weight, or that quality, by which all heavy bodies tend towards the center of the earth, or towards one another.*

Gravitation, *the preffure or action of an upper body upon another that is beneath it.*

H.

Heat, *a peculiar quality of fire excited by a mutual attrition of its particles.*

Hemifphere, *half of a fphere.*

Heterodox, *contrary to receiv'd opinions.*

Heterogeneous, *compounded of things of a different nature, kind, or quality.*

Homogeneous, *of the fame kind, nature, and properties.*

Horizon, *of any place upon the furface of the earth, is that great circle of the fphere, which in that place divides the upper hemifphere, or half compafs of the*

heavens, which we see, from the lower hemisphere, that is under us, and hid from our sight.

Horizontal parallax, *the difference between the true and apparent horizon.*

Hypothesis, *a supposition.*

Hypothetical, *belonging to an* hypothesis *or* supposition.

I.

Idea, *the image or representation of any thing conceived in the mind.*

Identical, *the same very individual person or thing spoken of.*

Immaterial, *a body not composed of gross matter.*

Immerged, *dipped, or plunged into.*

Immutable, *unchangeable, fixed, unalterable.*

Impetus, *the degree or force of motion impressed upon one thing by another.*

Impregnate, *to communicate the virtues of one body to another.*

Impulse, *pushing, driving, forcing.*

Inanimate, *lifeless, dead, without life or soul.*

Incident, *happening to, or falling out occasionally.*

Incurvate, *to bow or bend.*

Indefinite, *indeterminate.*

Infinite, *that hath no bounds, terms, or limits.*

Infinitum, (ad) *without end.*

Inflammable, *capable of being set on fire; of a combustible nature.*

Inflect, *to bow or bend.*

Ingenerable, *that cannot be ingender'd or produced.*

Ingenious, *quick-witted, full of wit or invention, curious.*

Ingenuous, *frank, free, honest, open, sincere, plain.*

Ingress, *entrance into.*

Innuendo, *something alluded to, a hint.*

Insect, *any very small living creature that flies or creeps,*

is

is not divided into joints and limbs, but surrounded with rings or divisions.

Inspiration, *an inspiring or breathing into.*

Instantaneous, *now, immediately, without any succession of time.*

Insulate, *cut off from all communication with the earth.*

Intellectual, *belonging to the understanding.*

Intense, *very great, or excessive.*

Intercostal, *lying between the ribs.*

Interior, *being on the inside.*

Internal, *that is within, inward.*

Interstices, *small or little spaces between the component parts of a body or matter.*

Intumescence, *swelling, rising, or puffing up.*

Invelope, *to wrap up, to infold.*

Investigation, *the tracing, finding out, or answering difficult questions.*

Invisible, *that cannot be seen, or perceived by the eye.*

L.

Laboratory, *a work-shop, where chymists,* &c. *perform their several operations.*

Latent, *lying hid, concealed.*

Latten, *iron tinned over, white iron.*

Lens, *a glass that either collects the rays of the sun passing thro' it into a point, or else disperses them farther abroad.*

Leyden experiment, *the electrical experiment first made by* Professor Muschenbroek.

Ligaments, *solid white substances used to tie the body, and chiefly the bones together.*

Lixivium, *a lye made of ashes,* &c.

Logical, *belonging to the rules of logic, or the art of reasoning.*

M.

Machine, *an engine, composed of several parts, set together*

gether by mechanical art, to raise or stop the motion of bodies, &c.

Macrocosm, *the great world, the whole universe, in contradistinction to the microcosm, which is commonly taken for the body of man.*

Magnetical Azimuth, *See the* Definition, p. 463.

Magnetical Meridian, *See* ditto, ibid.

Magnet, *the loadstone.*

Magnetic Needle, *the needle impregnated by the loadstone.*

Magnetism, *the attracting property of the loadstone.*

Malleolus, *a bone of the foot.*

Mass, *a heap or lump of any thing.*

Material, *whatever is made or composed of matter or substance.*

Maturation, *a ripening, hastening.*

Mechanical, *belonging to the mechanics.*

Mechanism of nature, or Mechanical agency, *the operation of matter upon matter, in contradistinction to a divine interposition.*

Medium, *that peculiar constitution or frame of any space, thro' which bodies move, as the air, water,* &c.

Menstruum, *a dissolving liquor, which eats thro' metals, and melts stones, as vinegar, aqua fortis,* &c.

Mercury, *quicksilver.*

Meridian, *a great circle passing thro' the poles of the world, and both the zenith and nadir.*

Metallic, *belonging to, or partaking of the nature of metals.*

Metaphor, *a figure in rhetoric, by which we put a strange and remote word for a proper one.*

Metaphysical, *abstracted, above nature or physics.*

Metaphysics, *that part of philosophy which treats of forms in general abstracted from matter.*

Microcosm, *a little world,* i. e. *the body of a man, so called,*

called, as a kind of compendium of the greater.

Minus, *less.*

Minute, *small, little.*

Mirrour or Mirror, *a looking glass, or the surface of any opaque body polished and made fit to reflect the rays of light that fall upon it.*

Modern, *new; of late time.*

Mundane, *belonging to the world.*

Muscle, *a bundle of thin and parallel plates of fleshy threads or fibres, inclosed by one membrane; an organical part of an animal body, the chief instrument of voluntary motion.*

N.

Nature, *the whole assemblage of created beings, and the orderly and regular succession and generation of one thing out of, or from another.*

Naturalist, *one that studies or is skilled in natural philosophy and physics.*

Negative, *a denying or gainsaying.*

Nitre, *salt-petre.*

Nodes, *are the points of intersection with the orbit of the sun, or where the tract or course of the sun, commonly called the ecliptic, and the orbits of the other planets that have latitude cross or cut one another.*

Non-electrics, *those bodies in which the electrical fluid is not fixed, as metals, water, animals, vegetables,* &c.

Nostrum, *a secret in any art or science, known to one or very few persons.*

Nutrition, *nourishing, a natural increase.*

O.

Oblique, *crooked, aside, out of a strait line.*

Object, *any thing which is opposed to our sight or any other senses; also subject or matter.*

Occult, *dark, hidden, unknown, secret.*

Occult qualities, *are such properties that divers bodies are endued with, the cause whereof is unknown.*

Ocular, *belonging to the eyes or sight.*

Odour, *the scent or smell that any thing emits.*

Optics, *the science of vision.*

Orb, *an hollow sphere or body, contained under two superficies, the one convex or external, the other concave or internal.*

Orbit, *the line described by any thing that moves round. in astronomy, it is the path or course in which a planet moves, or which a comet describes, the figures whereof are various.*

Ore, *metal unrefined, as it is mixed with the earth of the mine.*

Orthodox, *that is of a true or right opinion or belief.*

Oscillation, *a swinging up and down; also a vibration like the pendulum of a clock.*

Pabulum, *that part of any combustible body, that feeds increases, or continues the fire or burning in it.*

Parabolic curve, *always tends more and more to a parallelism with its diameter; but can never arrive thereat.*

Paradox, *a seeming contradiction or untruth, tho' in reality it is an absolute certainty.*

Parallax horizontal, *is when the sun, moon, or any other planet is in the horizon.*

Particle, *a small parcel, or little part.*

Pendent, *hanging down.*

Permanent, *durable, continuing, lasting.*

Permeate, *to penetrate into, or thro' the pores of any body.*

Perpendicular, *is when a right line hangs by, or a plane stands so upon another, as to lean no more one way than it does another.*

Perspiration, *a breathing or steaming through.*

Pervade, *to go through.*

Phæno-

Phænomena, *appearances of meteors, or any other signs in the air or heavens.*

Phial, *a little glass bottle.*

Physical, *natural, belonging to natural philosophy, or the art of physic.*

Physics, *natural philosophy, which considers the phænomena, causes, and effects, arising from, or productive of, the various motions, operations, affections, &c. of the heavens, meteors, or other natural bodies.*

Plane, *any extended flat superficies.*

Plane of the horizon, *the place that bounds the sight.*

Plenum, *space full of matter.*

Plus, *more.*

Pneuma, *the fine spirit or essence of æther.*

Pneumatics, *is that part of natural philosophy which teaches the properties of the air.*

Poles, *the points upon which the imaginary axis of the world, or any particular globe turns.*

Pores, *small interstices or void spaces between the particles of matter that constitute every body.*

Porphyry, *an exceeding hard sort of marble.*

Position, *a putting, placing, &c.*

Posteriori (à), *a mode of arguing from the effect to the cause.*

Postulates, *demands or assumptions; fundamental principles in any art or science, which are taken for granted, being such easy and self evident propositions as need no explanation or illustration to render them more plain.*

Predominant, *bearing chief sway, or over-ruling.*

Pressure, *a kind of motion which is impressed and propagated thro' a fluid medium.*

Primary, *first in order, principal, chief.*

Prime conductor, *that which conducts the electrical fluid immediately from the excited glass globe.*

Primum mobile, *the principal or moving cause or*

person

person in any affair.

Principal, *chief, main.*

Principle, *the first cause of the being or production of any thing; a motive or inducement.*

Priori (a), *a mode of arguing from the cause to the effect.*

Problem, *something proposed to be done, and is usually understood of constructing mathematical figures, and demonstrating the truth and reason of the process used to effect it.*

Projectile, *any thing thrown or cast with a considerable force from one.*

Propelled, *driven or thrust afar off, or forward.*

Propensity, *an inclination, or liking to a thing.*

Process, *the whole exact course of any operation or experiment.*

Proposition, *a thing proposed to be proved, or mathematically solved.*

Pro re natâ, *occasionally.*

Pulsation, *a knocking or striking, the beating of the pulse.*

Pulsion, *the driving or forcing any thing forward.*

Pupil, *a learner of any art or science of another.*

Putrefaction, *the act of corrupting, spoiling, wasting, or going to decay.*

Q.

Quadrature, *the making of any thing regularly square; or the finding out a square that shall be equal to the area of any other given figure.*

Queries, *questions, or something enquired about or asked after.*

R.

Radius, *a ray, beam or luminous strait line; in astronomy, is taken for the aspect or configuration of two stars; in geometry, is the semi-diameter of a circle, or the greatest sine.*

Rapid,